Appendix

This section contains technical references for use in analysis.

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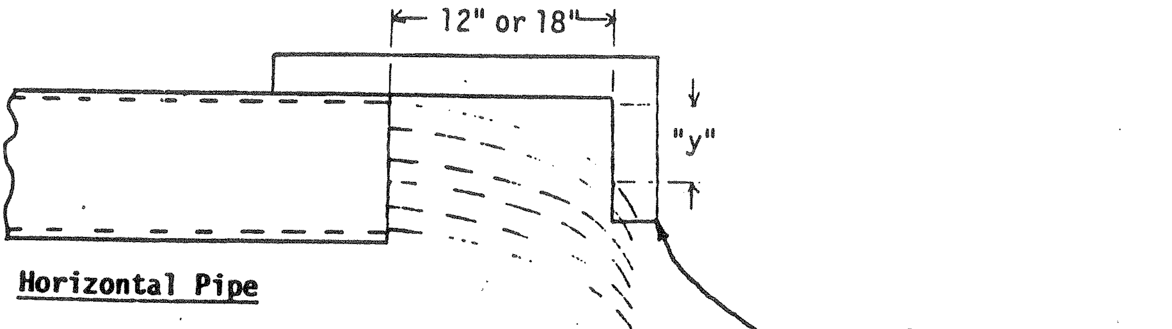
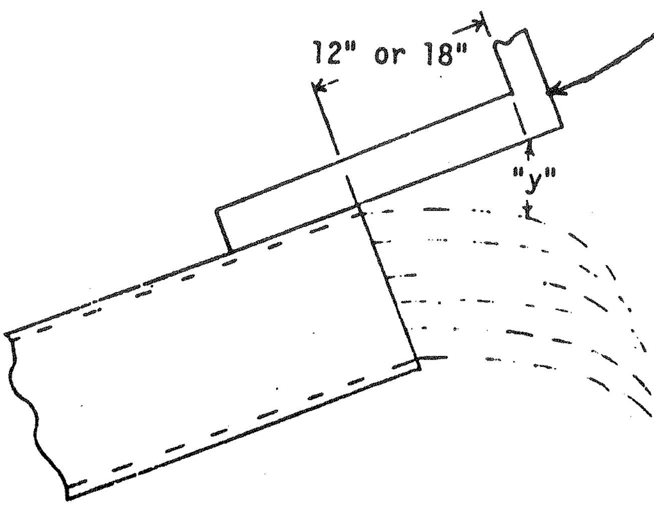
OPEN PIPE DISCHARGE MEASUREMENT

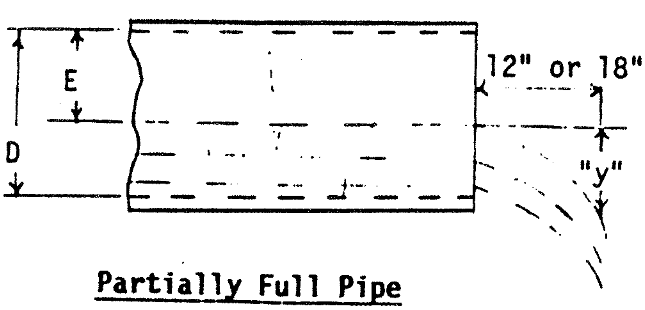
The flow from pipes may be approximated by measuring the fall (y) in a discharged stream of water for a horizontal (x) distance of 12 or 18 inches. Either a table or graph may be used for determining the discharge.



Horizontal Pipe



Inclined Pipe



Partially Full Pipe

FLOW FROM PARTIALLY FILLED PIPES

Divide "E" by "D" for per cent factor. Multiply flow for full pipe of "D" diameter by factor obtained from Table.

E - Measure of empty portion of pipe.

D - Measure of inside diameter of full pipe.

E/D	Factor	E/D	Factor
10	0.95	50	0.50
20	0.86	60	0.38
25	0.81	65	0.31
30	0.75	70	0.25
35	0.69	80	0.14
40	0.63	90	0.05
45	0.56	100	0.00

Table 1

OPEN PIPE DISCHARGE IN GALLONS PER MINUTE

"x" Distance = 18 inches
"y" Distance (inches)

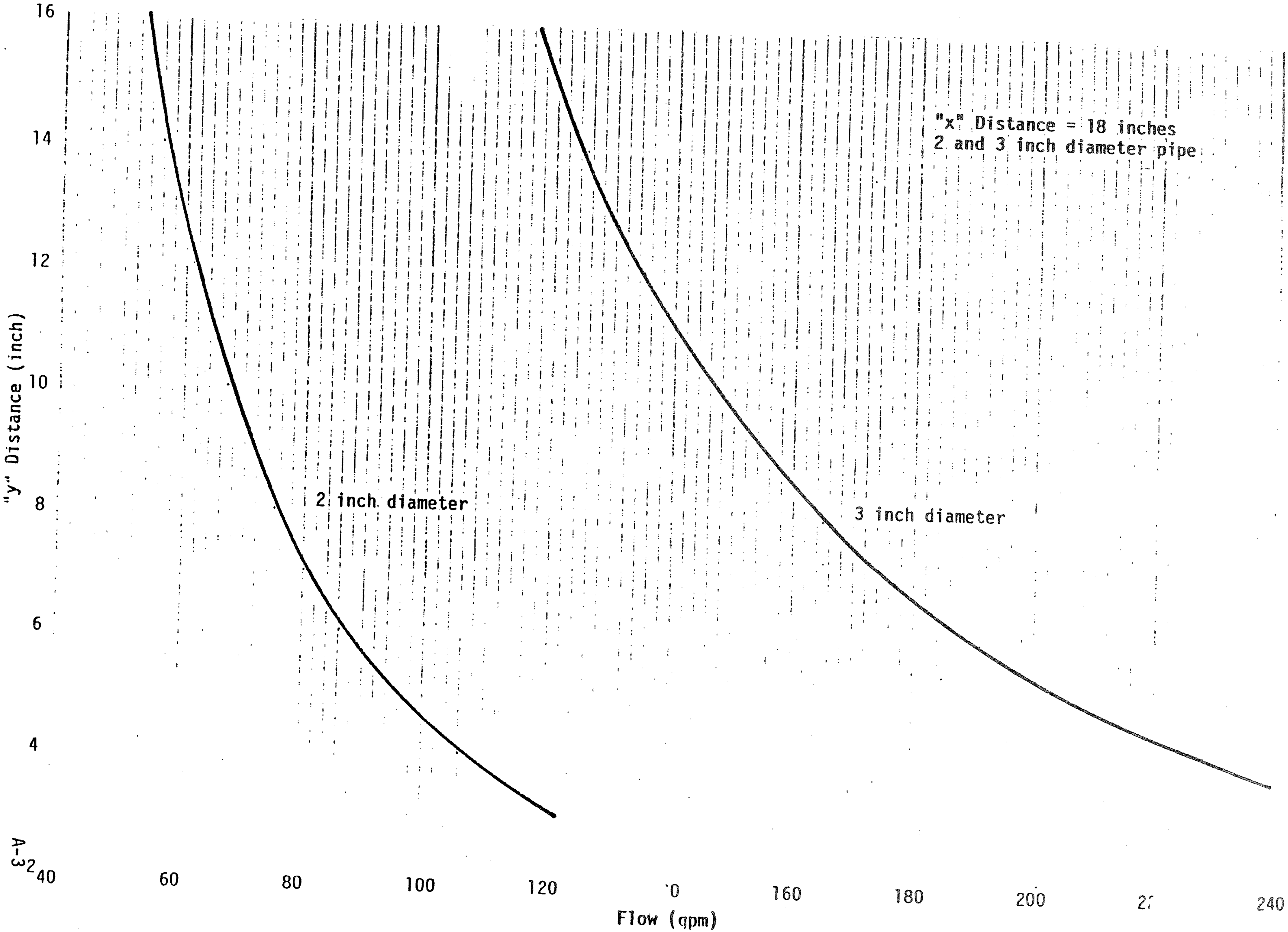
PIPE DIAMETER (inches)	3	4	5	6	7	8	10	12	14	16
2	122	106	95	86	80	75	67	61	56	53
3	270	234	209	191	177	165	148	135	125	117
4	464	402	359	328	304	284	254	232	215	201
5	729	632	565	516	477	447	399	365	338	316
6	1056	915	818	747	691	647	578	528	489	457
7	1419	1229	1099	1004	929	869	777	710	657	615
8	1830	1585	1418	1294	1198	1121	1002	915	847	792
10	2880	2494	2231	2036	1885	1764	1577	1440	1333	1247
12	4064	3520	3148	2874	2561	2489	2226	2032	1881	1760
VELOCITY (ft/sec)	11.8	10.2	9.1	8.3	7.7	7.2	6.4	5.9	5.4	5.1

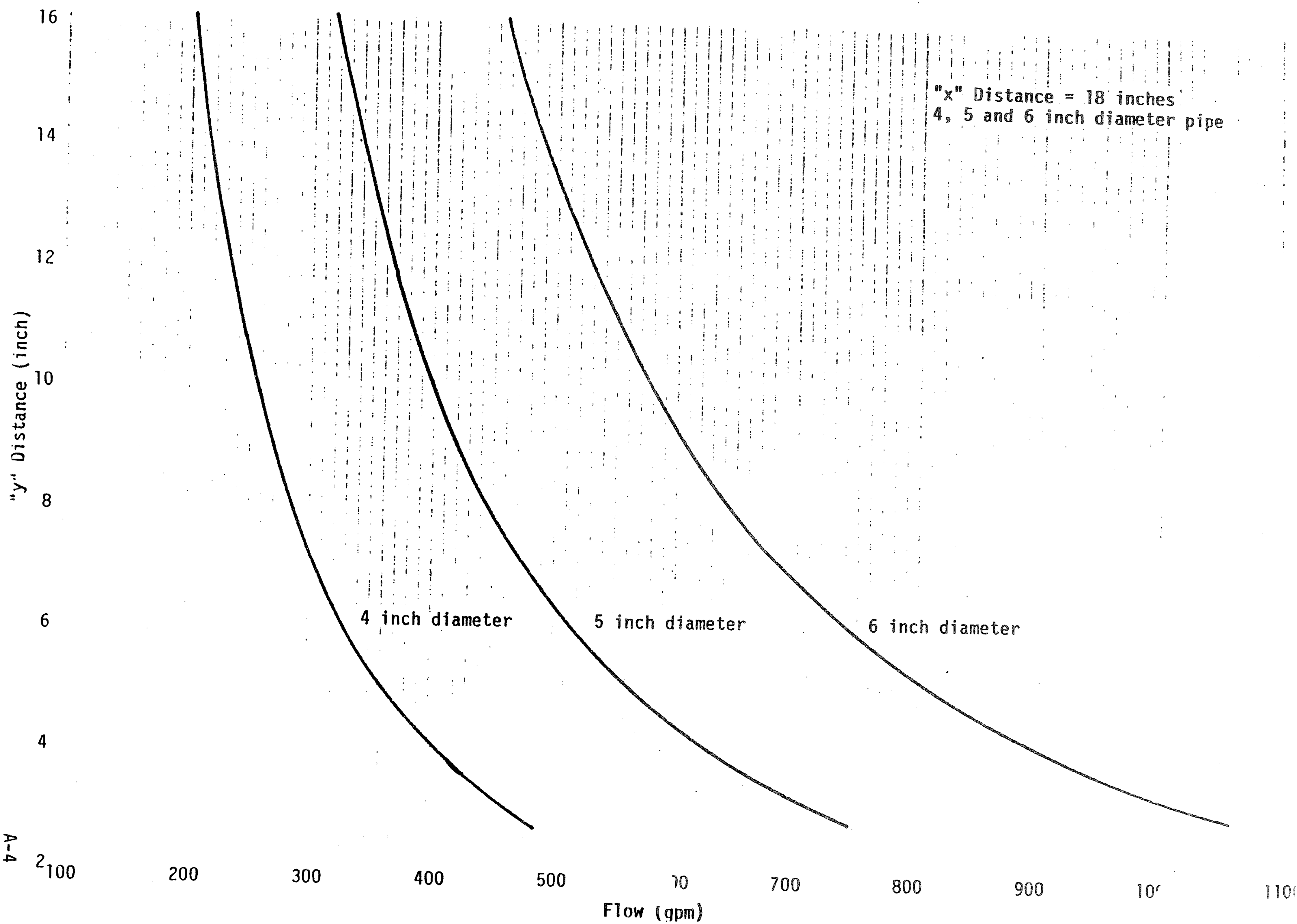
Table 2

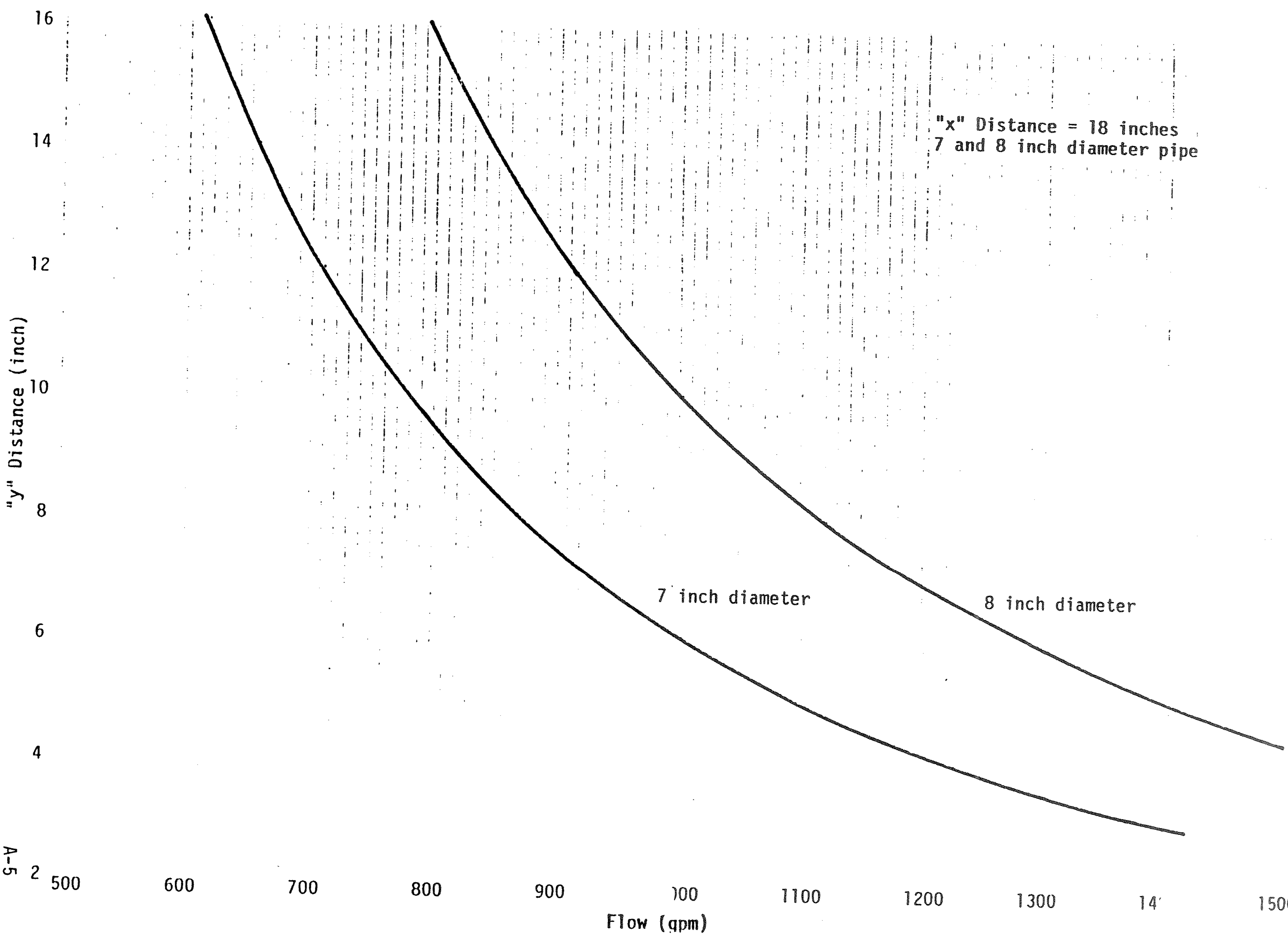
OPEN PIPE DISCHARGE IN GALLONS PER MINUTE

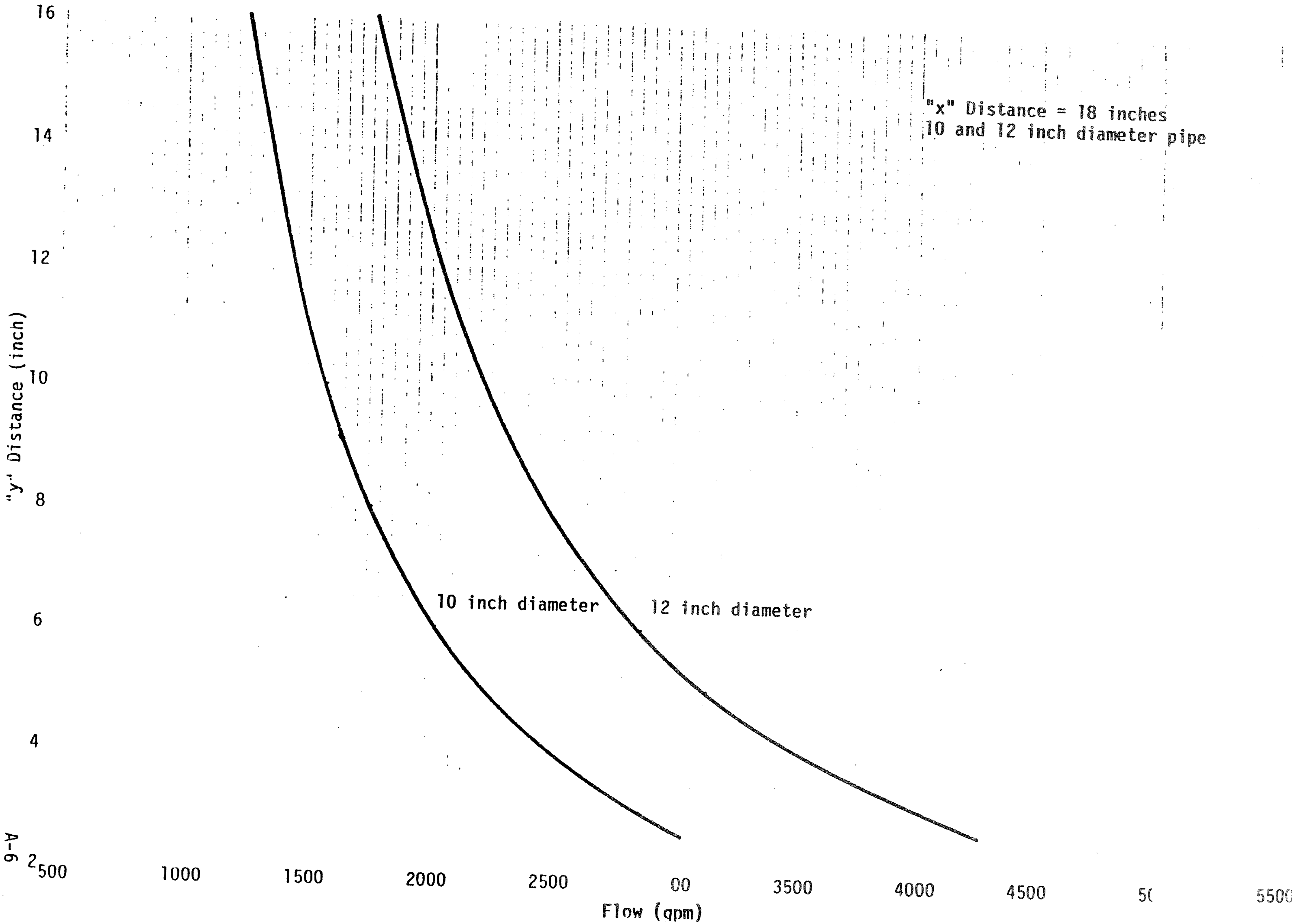
"x" Distance = 12 inches
"y" Distance (inches)

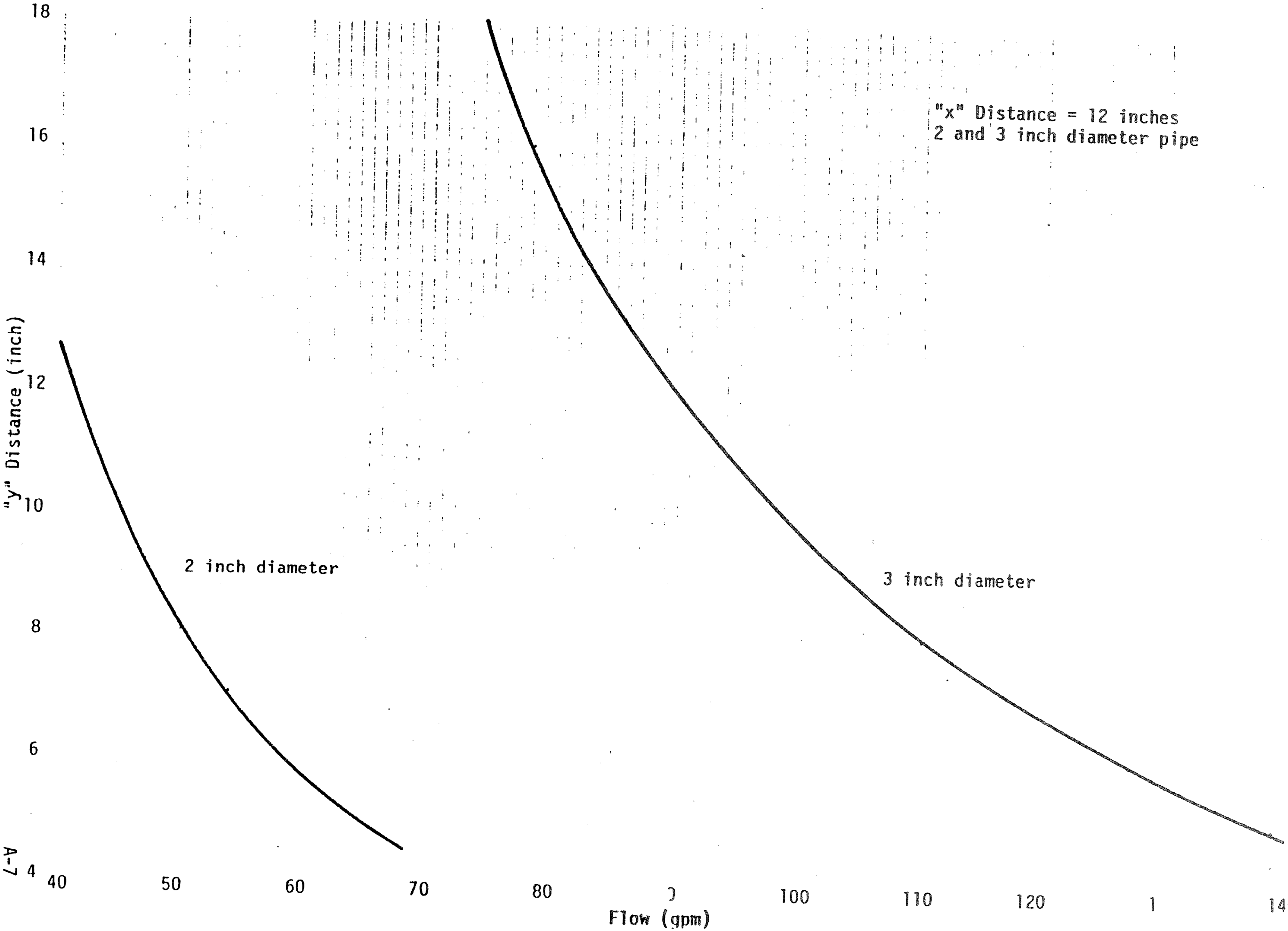
PIPE DIAMETER (inches)	5	6	7	8	10	12	14	16	20
2	64	58	54	50	45	41	38	36	32
3	139	127	118	110	99	90	83	78	70
4	232	212	196	184	164	150	139	130	116
5	371	339	313	293	262	239	222	207	185
6	545	498	461	431	386	352	326	305	273
7	733	669	619	579	518	473	438	410	366
8	945	863	799	747	668	610	565	528	473
10	1487	1358	1257	1176	1052	960	889	831	744
12	2135	1949	1804	1688	1510	1378	1276	1193	1067
VELOCITY (ft/sec)	6.1	5.5	5.1	4.8	4.3	3.9	3.6	3.4	3.0

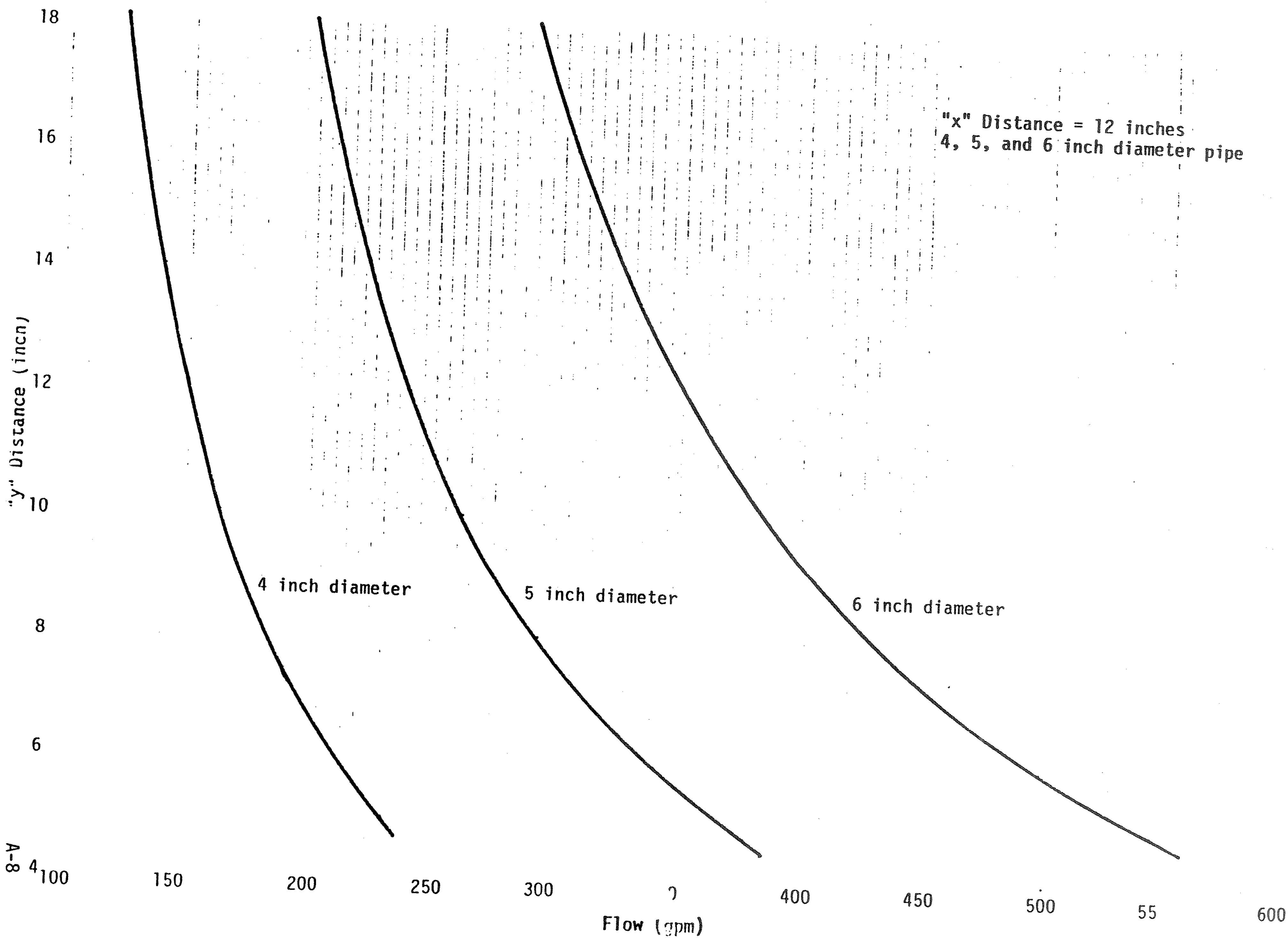

"x" Distance = 18 inches
2 and 3 inch diameter pipe
2 inch diameter
3 inch diameter
"y" Distance (inch)
16
14
12
10
8
6
4
40
60
80
100
120
160
180
200
240
Flow (gpm)


"x" Distance = 18 inches
4, 5 and 6 inch diameter pipe
4 inch diameter
5 inch diameter
6 inch diameter
"y" Distance (inch)
16
14
12
10
8
6
4
2
100
200
300
400
500
700
800
900
Flow (gpm)

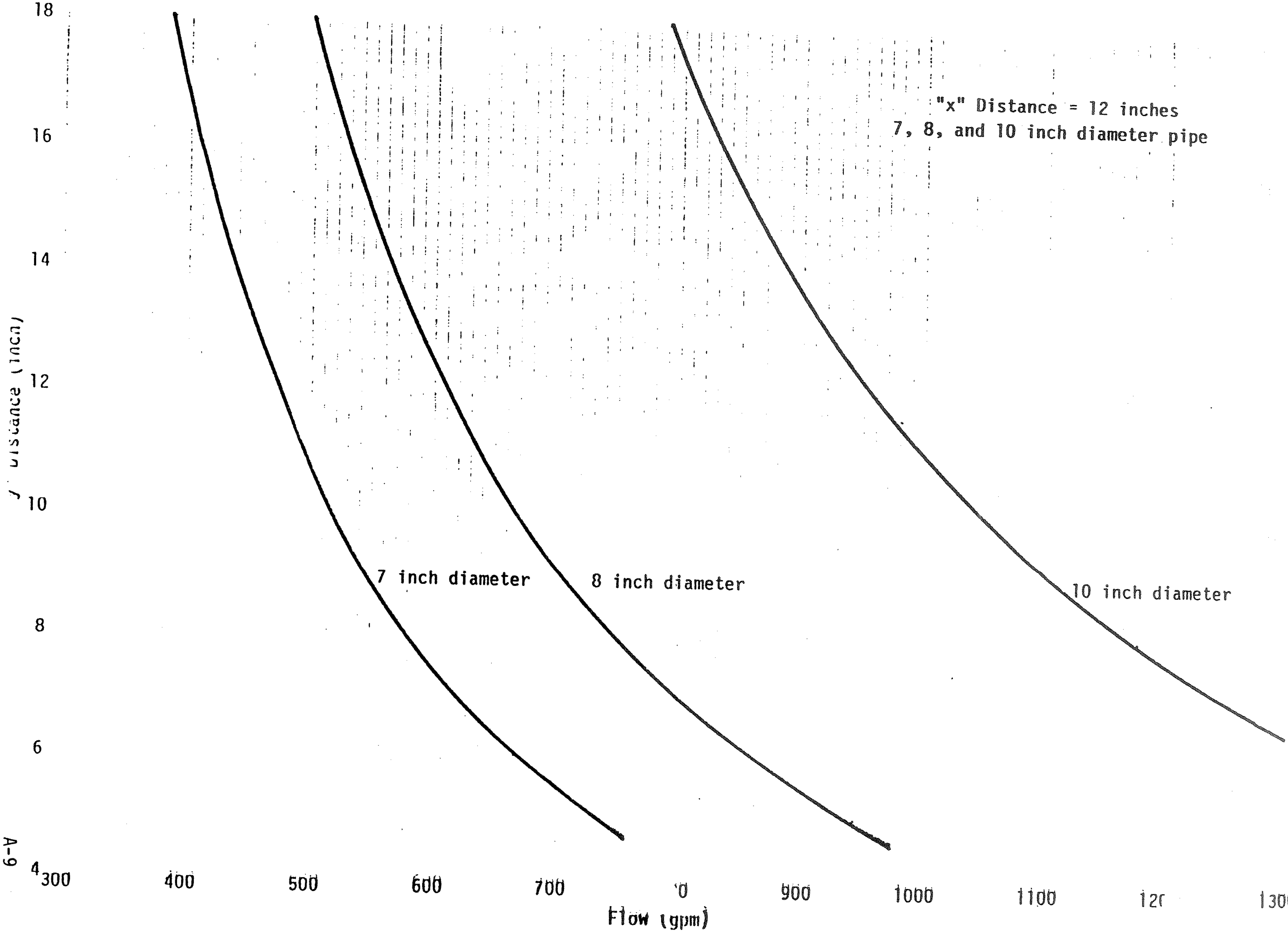

"x" Distance = 18 inches
7 and 8 inch diameter pipe
7 inch diameter
8 inch diameter
"y" Distance (inch)
16
14
12
10
8
6
4
2
500
600
700
800
900
)00
1100
1200
1300
14'
1500
Flow (qpm)

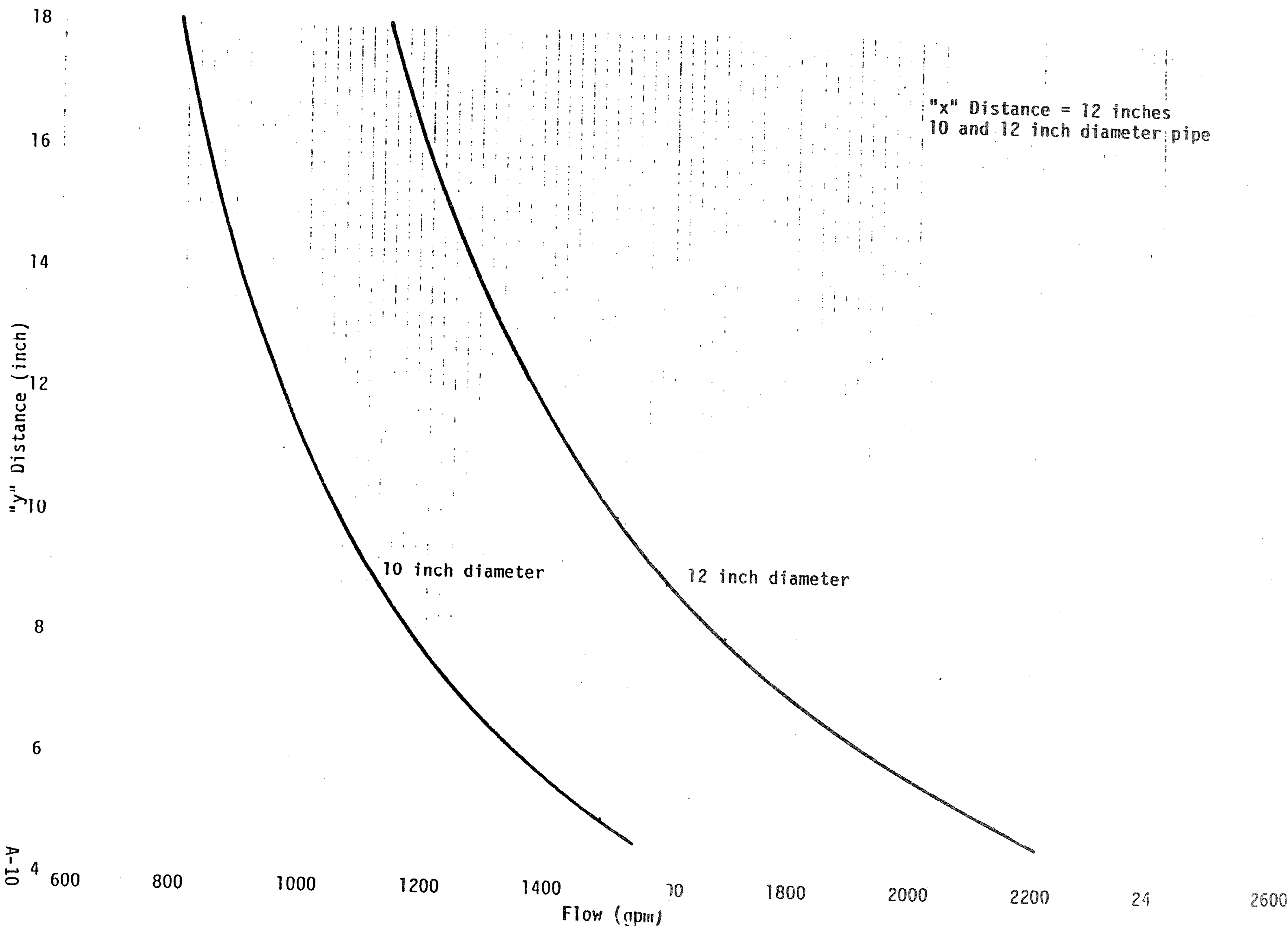

"x" Distance = 18 inches
10 and 12 inch diameter pipe
10 inch diameter
12 inch diameter
"y" Distance (inch)
16
14
12
10
8
6
4
2
500
1000
1500
2000
2500
00
3500
4000
4500
5(
5500
Flow (gpm)


"x" Distance = 12 inches
2 and 3 inch diameter pipe
2 inch diameter
3 inch diameter
"y" Distance (inch)
Flow (gpm)
18
16
14
12
10
8
6
4
40
50
60
70
80
100
110
120
140



"x" Distance = 12 inches
4, 5, and 6 inch diameter pipe
4 inch diameter
5 inch diameter
6 inch diameter
"y" Distance (incn)
18
16
14
12
10
8
6
4
100
150
200
250
300
400
450
500
55
600
Flow (gpm)

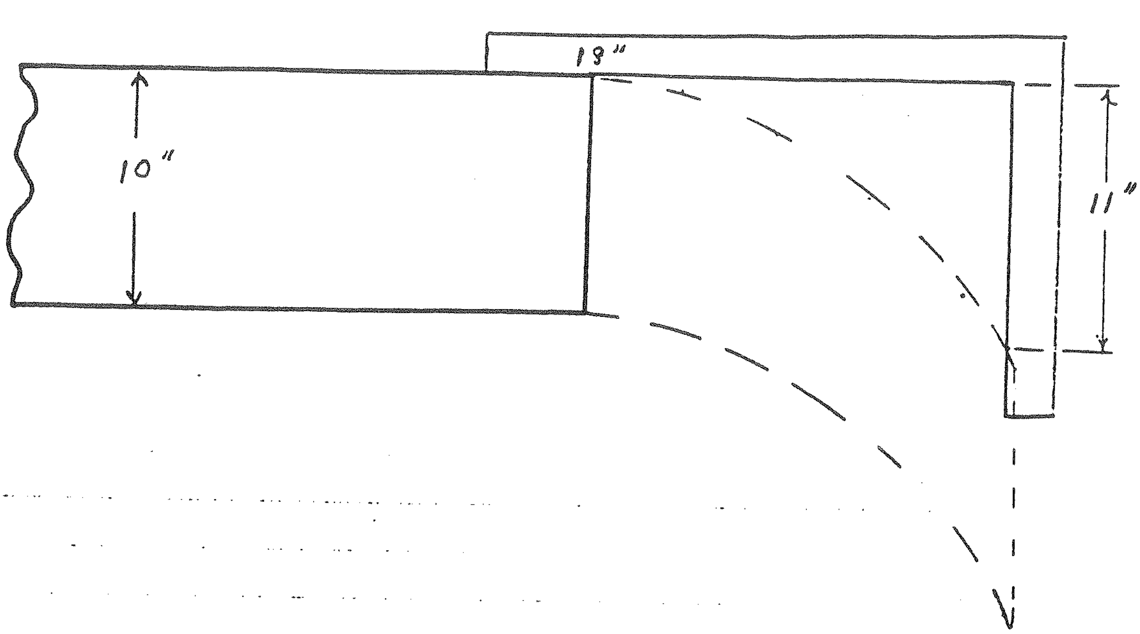

"x" Distance = 12 inches
7, 8, and 10 inch diameter pipe
7 inch diameter
8 inch diameter
10 inch diameter
Distance (inch)
18
16
14
12
10
8
6
4
300
400
500
600
700
900
1000
1100
1300
Flow (gpm)



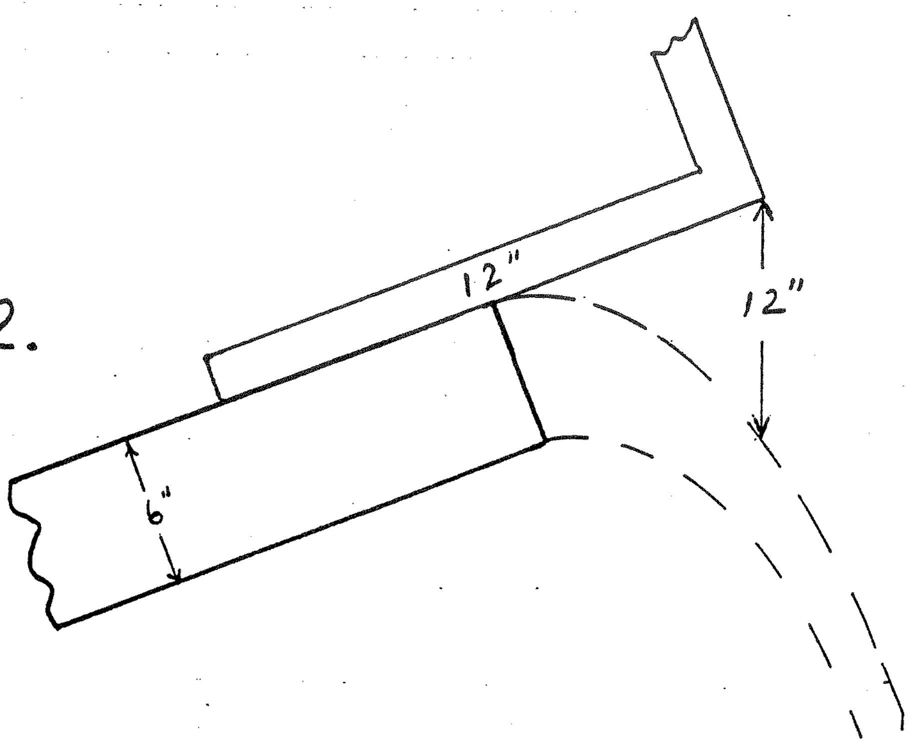
"x" Distance = 12 inches
10 and 12 inch diameter pipe
10 inch diameter
12 inch diameter
"y" Distance (inch)
18
16
14
12
10
8
6
4
600
800
1000
1200
1400
)0
1800
2000
2200
24
2600
Flow (gpm)

1

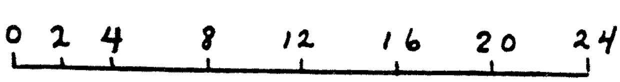
1.



2.

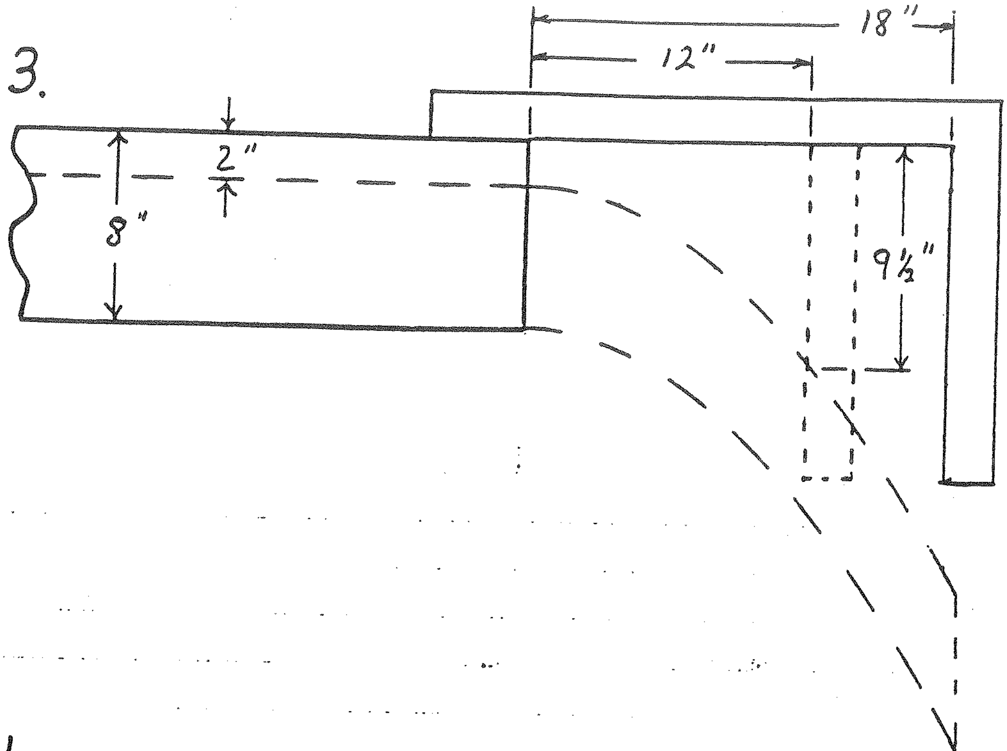


Scale (inches)

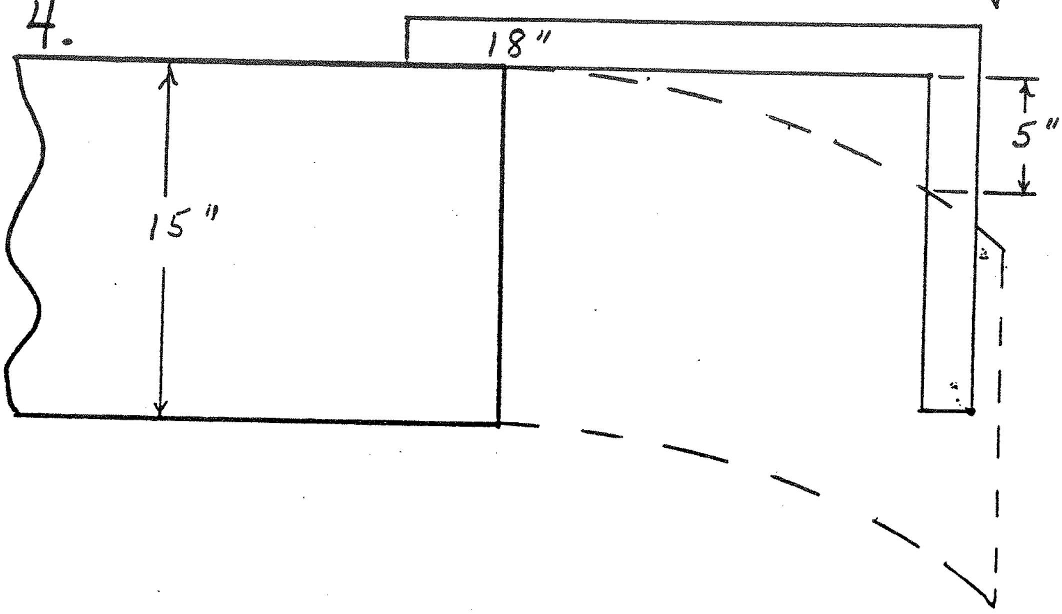


Open Pipe Discharge

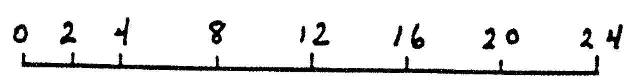
3.



4.

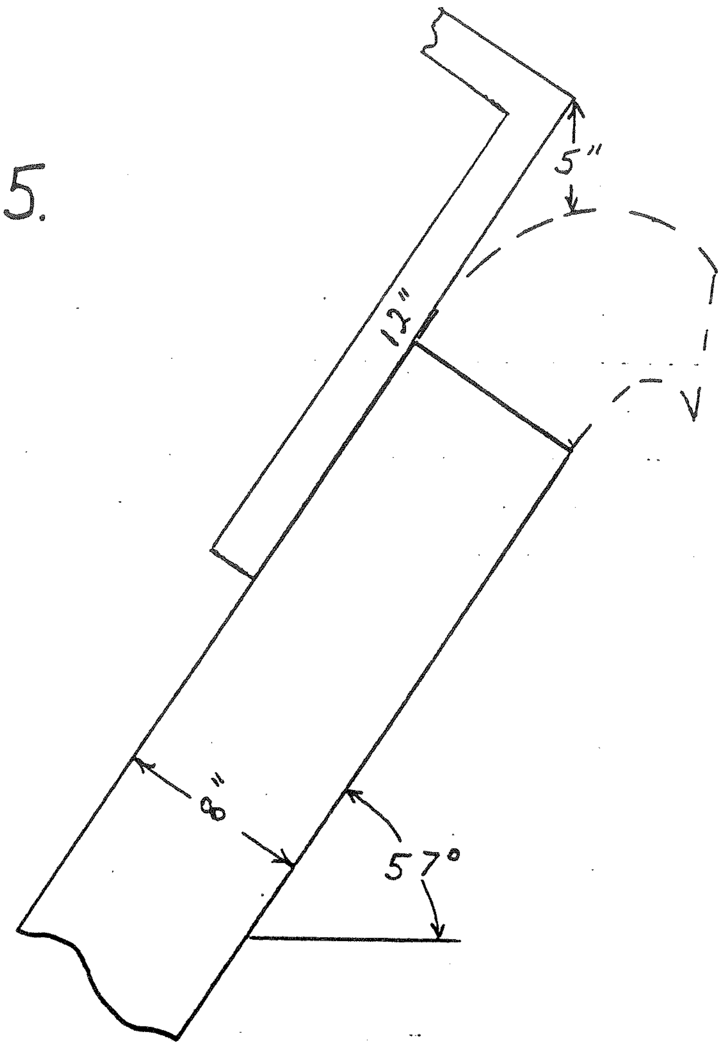


Scale (inches)

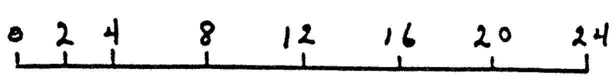


Open Pipe Discharge

5.



Scale (inches)



Open Pipe Discharge

OPEN PIPE DISCHARGE EXAMPLES

See Pages 1-3 for the drawings showing the discharge situations.

1. The water from a 10" level pipe drops 11" in 18". From Table 1, the values for 10" and 12" of drop may be averaged:

   Q = (1577 + 1440)/2 = 1508 gpm

   A graph may also be used to determine the discharge. Go to the "y" distance of 11" and move to the right to the 10" diameter line. From the intersection of the line, move down and read 1490 gpm.

2. Water from an inclined 6" pipe is measured to drop 12" below an extension of 12" beyond the end of the pipe. The discharge from this pipe may be read directly from Table 2. The discharge in Example No. 2 would be 352 gpm.

3. A partially full 8" pipe is flowing as shown in Example No. 3. A square is set at 18" out from the edge of the pipe, but it misses the stream. When the square is moved back to 12" from the edge of the pipe, the drop is 9½".

   The space between the pipe and the top of the water is 2" so the actual drop is only 7½". Going to the graph for 8" pipe, the <u>full</u> pipe discharge is determined to be 770 gpm. Referring to the bottom figure on the first page, the E-value is 2" and the D value 8", therefore...

   $$E/D = 2/8 = .25 \text{ or } 25\%$$

   From the table just to the right of the Figure, the "factor" can be determined. For 25%, the "factor" is 0.81.

   The partially full discharge is:

   $$Q = 770 \times 0.81 = 624 \text{ gpm}$$

4. The discharge from a 15" level pipe drops 5" in 18". Since 15" pipe is not shown, the bottom line of Table 1 can be used to determine the average velocity in the pipe is 9.1 ft/sec. Using the formula given

below, the discharge can be calculated.

$$Q = V \times D^2/.408$$

Where: Q = Pipe Discharge (gpm)
V = Average Water Velocity in the Pipe (ft./sec.)
D = Pipe Inside Diameter (in.)

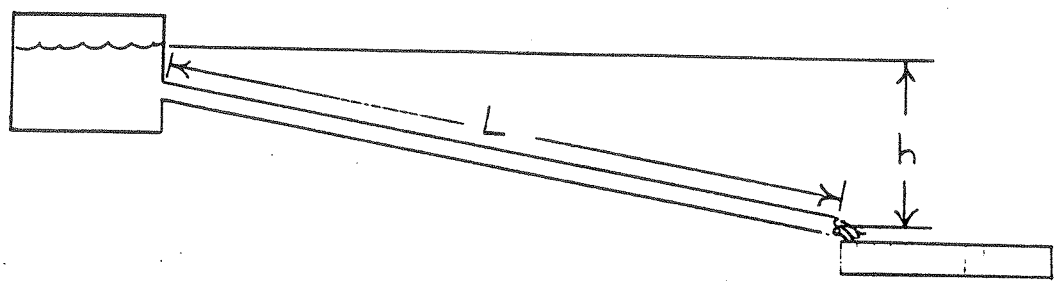
$$Q = 9.1 \times 15^2/.408 = 5018 \text{ gpm}$$

5. The pipe angle is greater than 45° with horizontal so the method shown here cannot be used. These problems can be solved on a case-by-case basis if the measurements shown on Example No. 5 are made. Just let me know if you have such a situation.

USING CHARTS FOR DETERMINING DISCHARGE THROUGH A PIPE FLOWING FULL.

Four parameters must be obtained or assumed to use the chart: length of pipeline involved (L), inside diameter of pipe in inches (d), type of pipe involved, and total vertical distance between water surfaces of inlet and outlet (h). The hydraulic gradient (s), in ft/ft and designated on left and right side of graph, is determined by dividing the total vertical height of water (h) by the length of pipeline or h /L. The proper chart for the type of pipe involved must be selected. (galvanized iron pipe in new/fair or old/poor condition or plastic/copper pipe). Move up left or right side of chart to calculated s value, then move horizontally to intersection with inclined line designating pipe diameter, from this point drop down vertically to point indicating flow in gpm. This is the discharge from that size pipe flowing full under the given or assumed parameters.

Example: Spring collection box - determine flow from pipe into stock tank



given	d	= 2 inches
	L	= 500 feet
	h	= 20 feet

type of pipe = galvanized pipe in good condition

determine s : s = h/L = 20/500 = 0.04

Move up side of graph to 0.04 and then over to intersection with line for 2 inch diameter pipe. Then move down vertically. This indicates a flow of 25 gpm

FYI - The dashed inclined lines marked V = 1,2,3 etc. give the velocity of the water in the pipe for the given intersect point

The charts are derived using the following Manning's Equation

$$\text{Mannings Formula: } Q = \frac{0.276}{n}\, d^{8/3}\, ,\, s^{1/2}$$

Q = Quantity of flow in gal./min.

d = Diameter of Pipe in inches

n = Coefficient of Roughness of Pipe

s = Hydraulic Gradient in ft/ft = h /L

h = Head Loss in Feet

L = Length of Pipe in Feet

Discharge through pipe flowing full

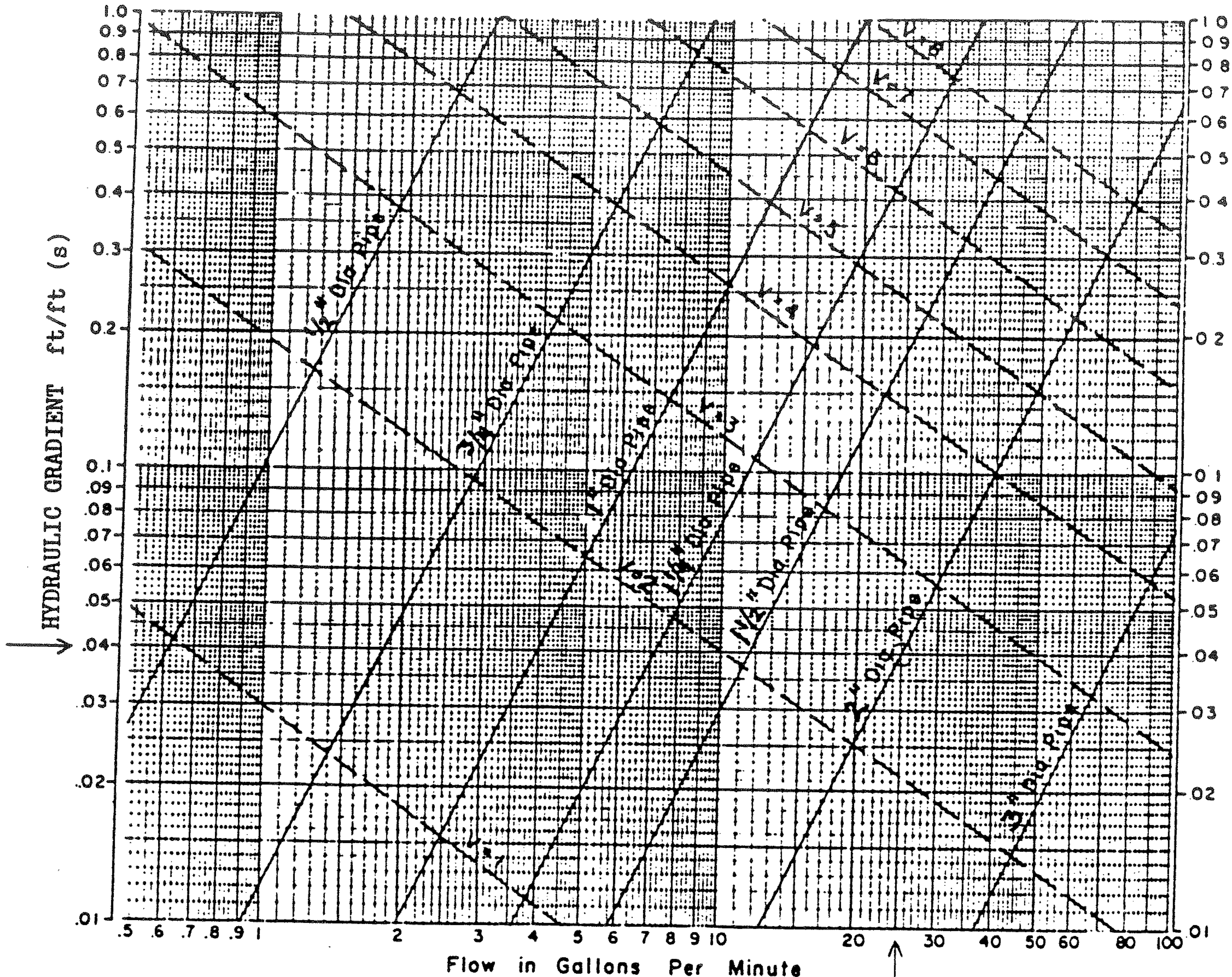


CHART FOR GALVANIZED IRON PIPE

(NEW or FAIR CONDITION)

(n= 0.014 for MANNING's EQUATION)

Discharge through pipe flowing full

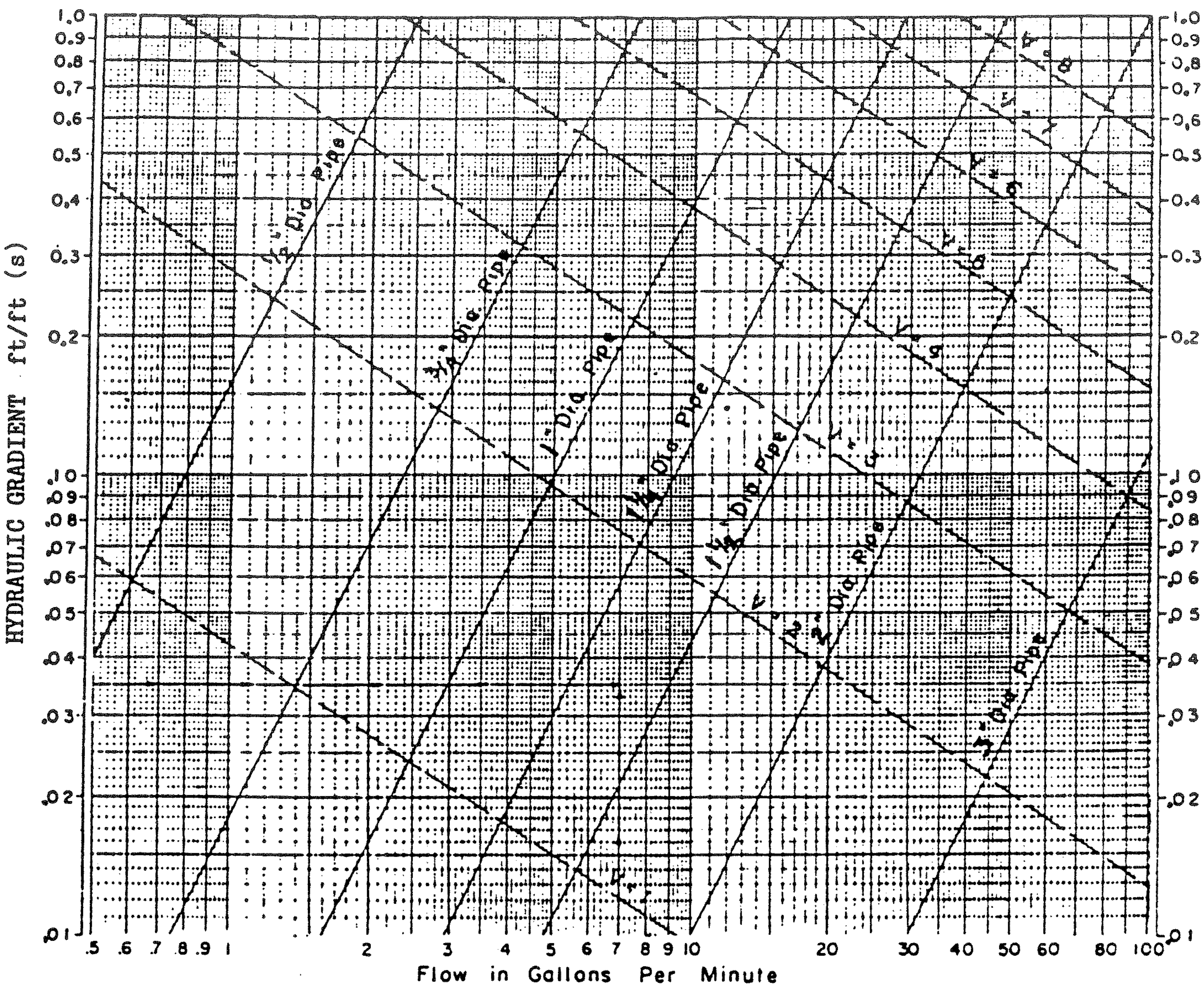


CHART FOR GALVANIZED IRON PIPE

(OLD or POOR CONDITION)
(n= 0.017 for MANNING's EQUATION)

Discharge through pipe flowing full

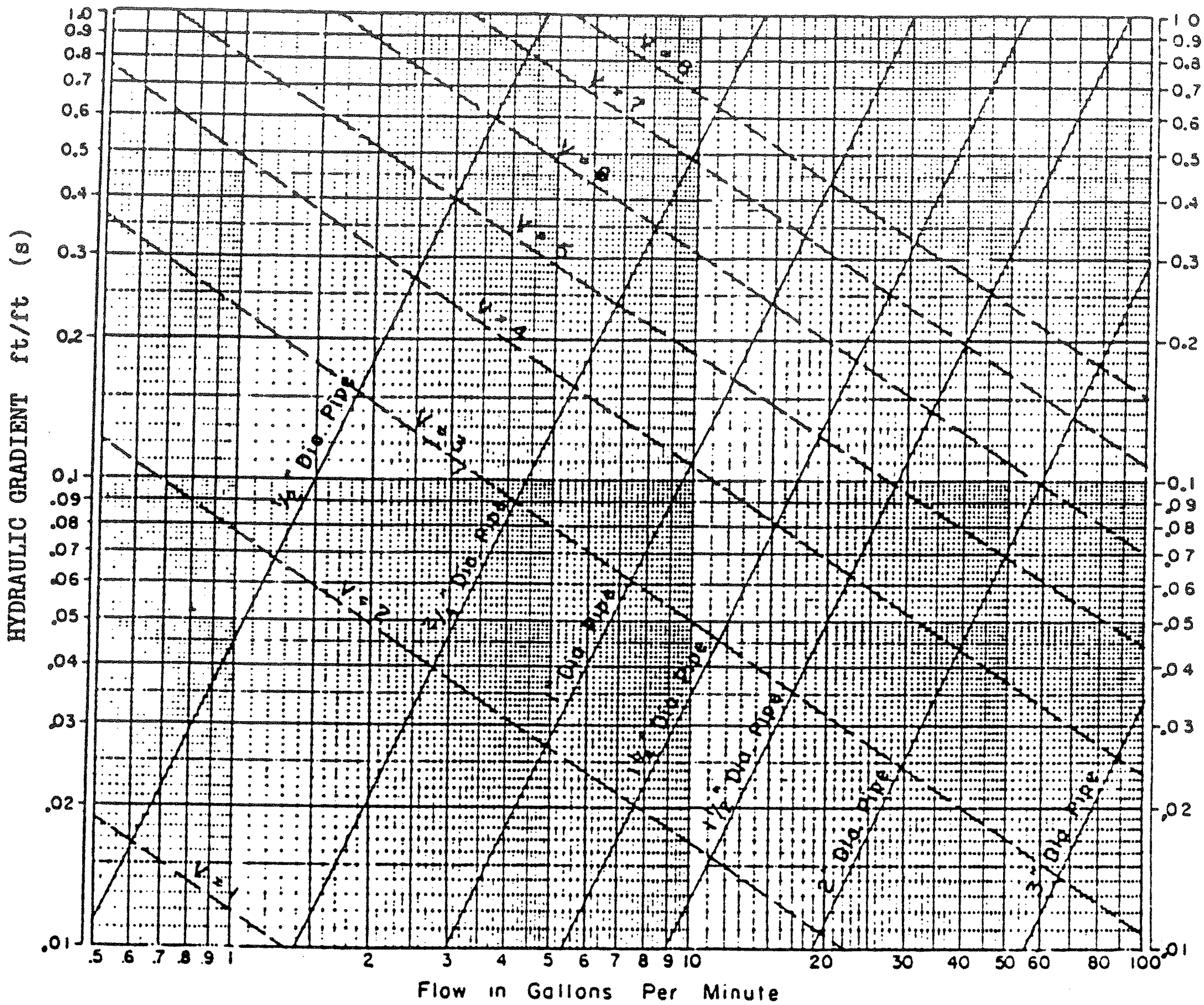


CHART FOR PLASTIC OR COPPER PIPE

(n= 0.009 for MANNING's EQUATION)

CURRENT METER MEASUREMENTS

Often ditches and streams have no measuring devices or gaging stations where discharge can be determined. In many instances a current meter measurement may be made to determine the flow. A current meter measures the velocity of water flowing past it.

A current meter is used to measure the average velocity of water movement through several partial sections of an open channel. Knowing the depth and width of the partial section, the discharge may be determined using equation (1).

$$q = a\, v \qquad (1)$$

Where: q = partial section discharge (ft^3/sec)
a = partial section cross sectional area (ft^2)
v = average velocity in the partial section [measured by the current meter] (ft/sec)

The discharge of the ditch or stream is obtained by summing the discharge in each partial section using equation (2).

$$Q = q_1 + q_2 + q_3 + \ldots + q_n \qquad (2)$$

Where: Q = stream or ditch discharge (ft^3/sec)
q_n = partial section discharge of the n^{th} section (ft^3/sec)

These instructions will only deal with measuring small channels, that is channels that are less than four feet deep and where the current is slow enough so that the channel may be waded. I will not discuss methods of placing current meters from bridges, boats, or cable ways since it is unlikely we will have the time or equipment to make that type of measurements.

These instructions will progress through the normal steps in the process of making current meter measurements as listed below.

1. Selection of a "good" reach of channel.
2. Setup of the current meter and wading rod.
3. Operation of the meter during actual measurement with pointers for special situations.

4. A methods of recording and summarizing the data from the current meter measurement.

5. A brief explanation of meter cleaning and maintenance.

At various places the mathematics of the recording and calculation process are discussed. Understanding of the formulas is not essential, however, the formulas do offer some background for the methods suggested. Following the exmaples (in the text and in Figure 5) should make the procedures and calculation methods clear.

Reach Selection and Set Up

When selecting a section of channel to measure with a current meter, attempt to locate the best site available. The user should try to find a section that has:

1. A straight, uniform reach of channel above and below the section, free of hydraulic jumps or falls.

2. A smooth bed free of large rocks and debris.

3. An even distribution of flow across the section.

4. A depth adquate to operate the chosen current meter (0.15 feet for a pygmy meter and 0.50 feet for a Price AA meter).

Once the section to be measured has been selected, a tag line* should be stretched across the section, purpendicular to the flow in the channel. If a tag line is not available, a steel or fiberglass tape may be used. The tag line is used to set the current meter at the desired locations across the stream. While locating the tag line, it is helpful to observe where the deep and/or swift partial sections are. this inforamtion is useful for both operator safety and selection of partial section widths as outlined in the "Flow Measurement" section.

> CAUTION: If the velocity of a section (in feet/second) times the depth (in feet) exceeds 10, it is advisable not to attempt wading measurement.

At this point, the meter, tailpiece, wading rod, and earphone should be assembled. The tail piece should be used only with the Price AA

*A tag line is a small diameter braided steel line with solder beads at 0.5, 1, 2, and 5 foot intervals.

meter. In rocky channels it may have to be removed if it interferes with the proper setting of the meter. Be sure to keep the bucket wheel off of the pivot pin with the raising nut (Price AA meter) or shipping pin (Pygmy meter) [see Figures 1 and 2] until just before the meter is to be used. If you are doing your own recording, all headings on the notes should be filled in to avoid overlooking important information.

Flow Measurement

The channel should be divided into 20 or more parts except for very small streams, where a somewhat smaller number of partial sections may be sufficient if the distance between verticals becomes less than one foot. The division is generally made so that there will be not more than 10 percent, and preferably not more than 5 percent, of the discharge between any two verticals. For some channels which are less than five feet wide, it is difficult to have partial sections with less than 10 percent of the total discharge.

Measurements should begin as close to the bank as possible. The shape of the bank, plant growth, and water depth all govern the ability to use the meter near the bank. The meter should then be placed at intervals to meet the criteria outlined in the previous paragraph.

Once a position on the tag line is selected, the depth of the water is measured. The wading rod is marked in 0.1 foot increments with 0.5 foot graduations having two marks and full foot graduations having three marks. Be sure to read the water level as it is flowing in the channel not the run up on the wading rod. Knowing the depth of the water, the meter can be set at the proper depth.

For water less than 2.5 feet in depth, the meter is generally set 0.6 times the water depth below the surface. This is commonly known as the six-tenths method. For water 2.5 feet deep or greater, two readings are made in each partial section, one at 0.2 and the other at 0.8 times the water depth below the surface. This is known as the two point method. The velocities at the two points are then averaged to determine an average velocity for the partial secion. In most cases the velocity at the 0.2 depth will be greater than at the 0.8 depth. In some cases where a channel suddenly becomes shallower, the normal velocity profile will reverse. Depths less than 0.5 foot should be avoided with the Price AA meter. The distrubance from the stream bed affects the meter accuracy at shallow depths, generally causing the current meter to understate the actual velocity.

For very shallow water (less than 0.5 foot deep), the current meter should be set at 0.5 times the water depth below the surface. Although this moves the meter from the depth where average velocity is most likely to be found, it reduces the interference from the channel bottom. If the channel will be shallow across the entire reach, it is best to use the pygmy meter for all of the measurements.

Two types of wading rods are generally used. One is a round sectional rod for which the 0.2, 0.6, or 0.8 depth has to be calculated, then the rod and meter is taken out of the water to make the proper meter placement. The other type of wading rod is called a top setting rod. It has a hexagonal rod on which the meter moves. A second round rod, behind the hexagonal rod is marked in feet. The handle of top setting rod is marked in tenths of feet. By setting the proper feet and tenths on the round rod, the meter is placed at 0.6 depth. For the two-point method, twice and half water depth are set on the round rod for 0.2 and 0.8 depth respectively.

> EXAMPLE: If water, 2.2 feet deep is being measured, the following procedure would be used to set the meter depth. NOTE: The two point method is shown as an example only. Normally only one velocity measurement, at 0.6 depth, would be made where the water depth is 2.2 feet.
>
> Top Setting Rod
> For the 0.6 method, set the two foot mark on the round rod across from the 0.2 foot mark on the rod handle. For the two point method, the 0.2 depth setting would be made by setting the four foot mark across from the 0.4 foot mark (4.4 feet = 2 X 2.2 feet). The meter would be set at the 0.8 depth by setting the round rod at 1.1 feet (1.1 feet = 0.5 X 2.2 feet).
>
> Round Wading Rod
> The round rod measures the distance from the bottom of the channel. The meter setting is measured from the water surface so the meter setting depth can be subtracted from the total water depth or the meter can be set from the bottom, using a different set of depth factors. The settings would be 0.8, 0.4, and 0.2 depth from the bottom for the normal 0.2, 0.6 and 0.8 setting depths, respectively.
>
> The 0.6 method would require a setting 1.32 feet below the water surface (0.6 x 2.2 feet) or 0.88 feet from the bottom (2.20 feet - 1.32 feet). Note that setting 0.4 X 2.2 feet from the bottom would result in the same setting.
>
> The 0.2 setting would be at 1.76 feet from the bottom (2.2 feet - 0.2 X 2.2 feet). For the 0.8 setting, the meter would be 0.44 feet from the channel bottom (2.2 feet - 0.8 X 2.2 feet).

To determine the velocity at any point, the number of revolutions (clicks) of the meter are timed. Figure 3 shows a calibration chart similar to one that would come with a Price AA meter. Note that the time scale runs from 40 to 70 seconds. It is most convenient to count a number of revolutions listed at the top of the chart in the 40 - 70 second range. For the pygmy meter, the number of revolutions can be divided by the time in seconds to obtain the water velocity in feet per second. It is advisable to always time at least 40 seconds to average any natural water velocity fluctuations. If the velocity is highly variable, that is the clicks are very uneven, it may be advisable to time for a longer period to "average" the velocity variation.

It should be noted that the Price AA meter has two contact binding posts. One connection causes a click each revolution of the bucket wheel while the other contact causes a click every 5^{th} revolution. The connections are generally marked with a "1" and "5" on the contact chamber.

Every effort should be made to minimize the effect of the operator's presence in the stream. The operator should stand just behind the tag line and at least 1.5 feet to the side of the meter. If the channel is small, it is advisable to work from the shore or from a bridge constructed from a sturdy plank.

Discharge Calculations

As previously mentioned, the discharge through any partial section is equal to the cross sectional area times the velocity [see equation (1)]. The velocity is given by the current meter rating chart (see Figure 3). The area is determined by what is called the mid-section method.

In the mid-section method of making a current meter measurement, it is assumed that the velocity sample at each location represents the mean velocity in a partial rectangular area. The area extends laterally from half the distance from the preceding meter location to half the distance to the next and vertically, from the water surface to the measured depth (see Figure 4).

The cross section is defined by depths at locations 1, 2, 3, 4, ... n (see Figure 4). At each location, the velocities are sampled by current meter to obtain the mean computed for any partial section at location $_n$ as

$$q_n = v_n \left[\frac{(b_n - b_{(n-1)})}{2} + \frac{(b_{(n+1)} - b_n)}{2}\right] d_n \quad \text{or}$$

$$= v_n \left[\frac{b_{(n+1)} - b_{(n-1)}}{2}\right] d_n \qquad (3)$$

WHERE: q_n = discharge through partial section n (ft^3/sec)

v_n = mean velocity at location n (ft/sec)

b_n = distance from initial point to location n (ft)

$b_{(n-1)}$ = distance from initial point to preceding location (feet)

$b_{(n+1)}$ = distance from initial point to next location (ft)

d_n = depth of water at location n (ft)

Thus, for example, the discharge through partial section 4 (heavily outlined in Figure 4) is

$$q_4 = v_4 \left[\frac{b_5 - b_3}{2}\right] d_4$$

The procedure is similar when n is at an end section. The "preceding location" at the beginning of the cross section is considered coincident with location 1; the "next location" at the end of the cross section is considered coincident with location n. Thus,

$$q_1 = v_1 \left[\frac{b_2 - b_1}{2}\right] d_1 \tag{4}$$

and

$$q_n = v_n \left[\frac{b_n - b_{(n-1)}}{2}\right] d_n \tag{5}$$

For example, as shown in Figure 4, q_1 is zero because the depth at observation point 1 is zero. However, when the cross-section boundary is a vertical bank at the edge of the water as at location n in Figure 4, the depth is not zero and velocity at the end section may or may not be zero. The formula for q_1 or q_n is used whenever there is water only on one side of an observation point such as at piers, abutments, large rocks, and islands. It is necessary to estimate the velocity at an end section a some percentage (usually 50%) or the velocity of the adjacent section because it is impossible to accurately measure the velocity close to a boundary with a current meter.

Recording Data

The data gathered is put on a form prepared for such use. Figure 5 shows a completed sheet. The columns are completed as discussed below:

1. The distance values are read from the tag line for each edge of the stream and each current meter setting. L.E.W. and R.E.W. stand for left edge of water and right edge of water. L.E.W. and R.E.W. refer to the left and right banks when facing downstream. When taking current meter measurements, you will facing upstream so the L.E.W. will be at your right hand side.

2. The width is determined by calculating the distance from the previous section to next section. With reference to Figure 4, the following equation applies:

$$w_n = \frac{b_{(n+1)} - b_{(n-1)}}{2} \qquad (6)$$

WHERE: w_n = width of section n (ft)

$b_{(n-1)}$ = distance from initial point to preceding location (ft)

$b_{(n+1)}$ = distance from initial point to next location (ft)

Note that the w_n is equal to the term in brackets in equation (3). For the end sections, w_1 and w_n can be equated to the terms in brackets in equations (4) and (5) respectively.

3. The depth is read from the wading rod.

4. The depth of observation will generally be 0.6 or 0.2 and 0.8 depending on the water depth or other conditions.

5. The number of revolutions are counted by counting the clicks generated by the meter contacts. Remember to count by 5's if the penta ("5") contact is being used on the Price AA meter.

6. The time in seconds is read from the stop watch.

7. The velocity at point column is used when the two-point method is used. Note only columns 4-7 and 12 are used for the 0.8 depth.

8. The mean velocity in vertical is used to record single velocity readings at 0.6 or 0.5 depth or to record the average of the 0.2 and 0.8 depth readings. Note that at the R.E.W., where the depth was not zero, the velocity was assumed to be 50 percent of the velocity at the nearest section.

9. The mean velocity in section is used only if the current is not at right angles with the tag line. The value in column 12 is then taken times the velocity in column 8 to calculate the value in column 9.

10. The area is the product of the depth and the width (column 2 times column 3).

11. This may be disregarded.

12. The angle coefficient is sine of the angle between the tag line and the current meter. It can be determined by orienting the note sheet in the direction of the current meter. Put the bull's eye on the right side of the page over the tag line and read the angle coefficient over the tag line on the left side of the page.

13. The discharge is the product of the velocity and the area (column 8 or 9 times column 10).

Note that columns 2, 10, and 13 are totaled. Column 2 as a check, column 10 to obtain the full channel cross sectional area, and column 13 to calculate the channel discharge.

<u>Maintenance</u>

All current meters require frequent cleaning, oiling, and maintenance. Refer to the manual with your current meter or Reference No. 3 for more detailed information.

> CAUTION: Always release the raising nut on the Price AA meter before removing the contact chamber cap. Removing the cap while the shaft is against it (raising nut not released) may result in a bent shaft.

After each day's use, the meter should be cleaned and oiled. Cleaning is accomplished by removing the pivot pin, contact chamber cap, and bucket wheel (on pygmy meter only). The meter is then washed under hot tap water to remove any mud, sand or other foreign material. Make a special effort to clean the pivot bearing. The meter should be dried with a rag or soft paper towel. A cotton swab may be used to clean the pivot bearing.

The contact chamber should be free of water before storage. The contact chamber should be removed and the water shaken out. The hot water will warm the metal of the contact chamber so that once the drops are shaken out, any thin film of water will evaporate.

After all meter parts are clean and dry, they should be reassembled. Oil should be applied to all bearing surfaces, gears, and to the contact chamber cap threads.

After assembly, a spin test should be made. The meter should be mounted so that the shaft is vertical on a testing board in an area free of air currents. The bucket wheel should be given a quick turn by hand. The time that the bucket wheel spins is timed. The Price AA meter should spin for 1.5 to 4 minutes and the pygmy meter should turn for 30 to 90 seconds. If the bucket wheel does not spin for the minimum time, check for the following:

1. A worn pivot bearing. Run your finger nail toward the point of the bearing. If you feel a "catch", the pin is worn. Replace the pivot.

2. Improper lubrication. Re-clean the meter and re-oil.

3. Improperly adjusted contact wire. Use an opened paper clip to gently move the contact wire away from the shaft. Only allow enough contact so that electrical contact is made with the eccentric on the bucket wheel or penta shaft.

4. Bent shaft or yoke. Have a qualified technician replace the damaged part.

Important Points

When making current meter measurements, a set procedure should be followed. A summary of the steps are listed below.

1. Select a straight, uniform reach of stream.

2. Put a tag line across the stream at a right angle to the current.

3. Assemble your equipment.

4. Make the measurements and record the data, keeping in mind that smaller sections generally result in better discharge measurements.

5. Compute the discharge using accepted computation methods.

6. Clean and adjust the meter.

TABLE 1

SELECTED REFERENCES

1. Investigations of Methods and Equipment Used in Stream Gaging, Part 1. Performance of Current Meters in Water of Shallow Depth, Geological Survey Water Supply Paper 868-A by C. H. Pierce, 1941.

2. Stream-Gaging Procedure, Geological Survey Water-Supply Paper 888 by D. M. Corbett, 1943.

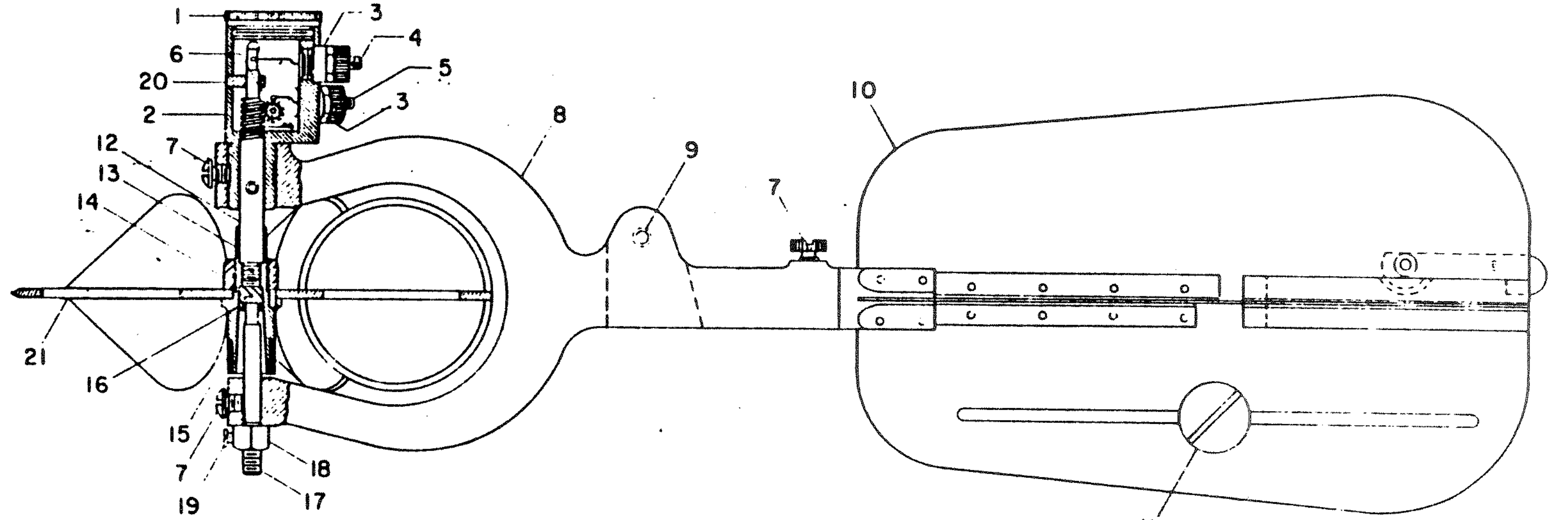
3. Techniques of Water-Resource Investigations of the United States Geological Survey, Calibration and Maintenance of Vertical-Axis Type Current Meters, Book 8, Chapter B2 by G. F. Smoot, 1968.

4. Techniques of Water-Resource Investigations of the United States Geological Survey, Discharge Measurements at Gaging Stations, Book 3, Chapter A8 by T. J. Buchanan, 1969.

5. Techniques of Water-Resource Investigations of the United States Geological Survey, General Procedure for Gaging Streams, Book 3, Chapter A6 by R. W. Carter & Jacob Davidian, 1968.

6. Water Measurement Manual, 2nd ed., U. S. Department of Interior, Bureau of Reclamation, 1967.

Figure 1

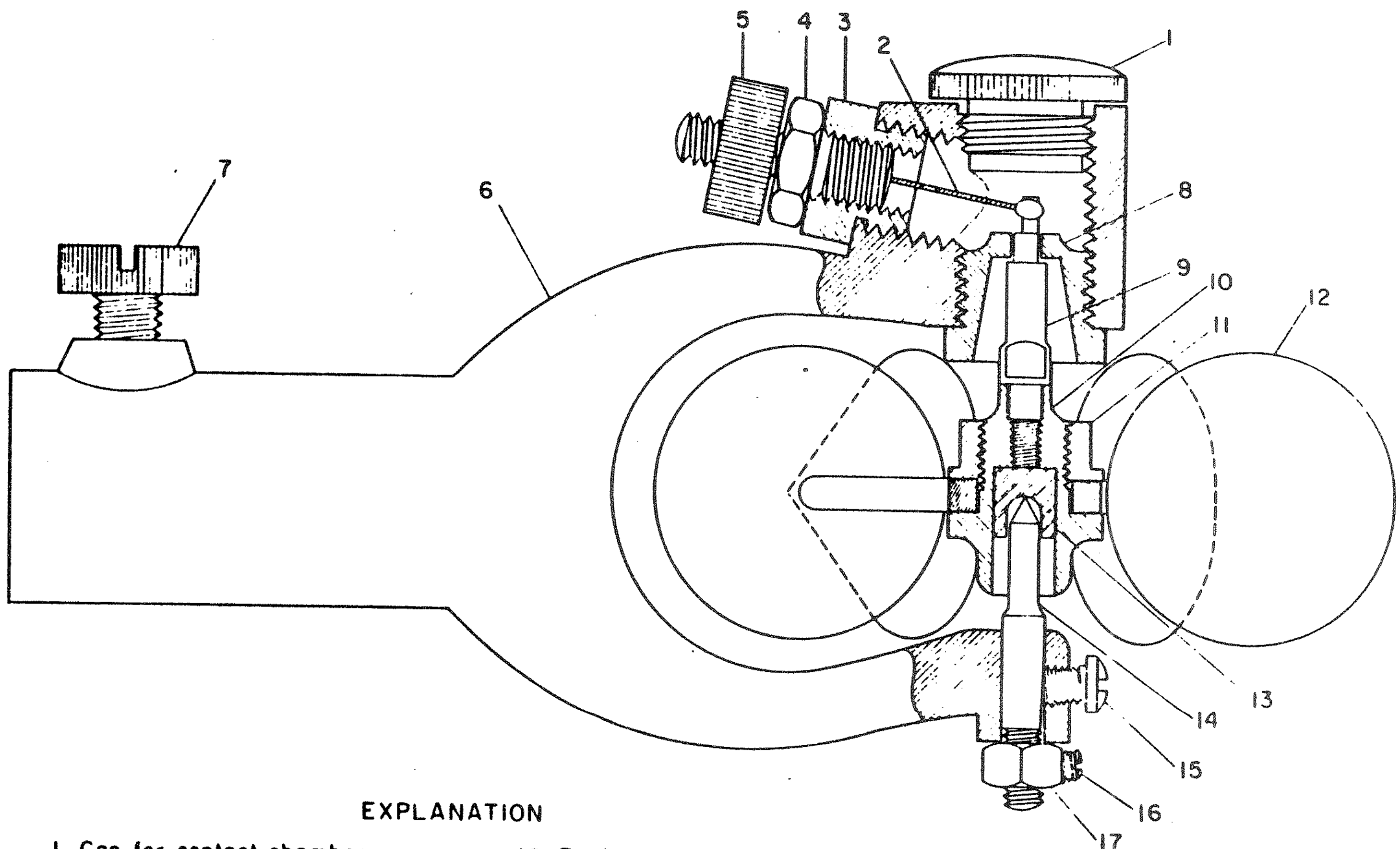


EXPLANATION

1. Cap for contact chamber	11. Balance weight
2. Contact chamber	12. Shaft
3. Insulating bushing for contact binding post	13. Bucket-wheel hub
4. Single-contact binding post	14. Bucket-wheel hub nut
5. Penta-contact binding post	15. Raising nut
6. Penta gear	16. Pivot bearing
7. Set screw	17. Pivot
8. Yoke	18. Pivot-adjusting nut
9. Hole for hanger screw	19. Keeper screw for pivot-adjusting nut
10. Tailpiece	20. Bearing lug
	21. Bucket wheel

.—Assembly diagram of type-AA Price current meter.

Figure 2



EXPLANATION

1. Cap for contact chamber
2. Binding-post beaded wire
3. Binding-post insulating bushing
4. Binding-post body
5. Binding-post nut
6. Yoke
7. Yoke set screw
8. Upper bearing
9. Shaft
10. Bucket-wheel hub
11. Bucket-wheel hub nut
12. Bucket wheel
13. Pivot bearing
14. Pivot
15. Pivot set screw
16. Pivot-adjusting nut keeper screw
17. Pivot-adjusting nut

—Assembly diagram of pygmy current meter.

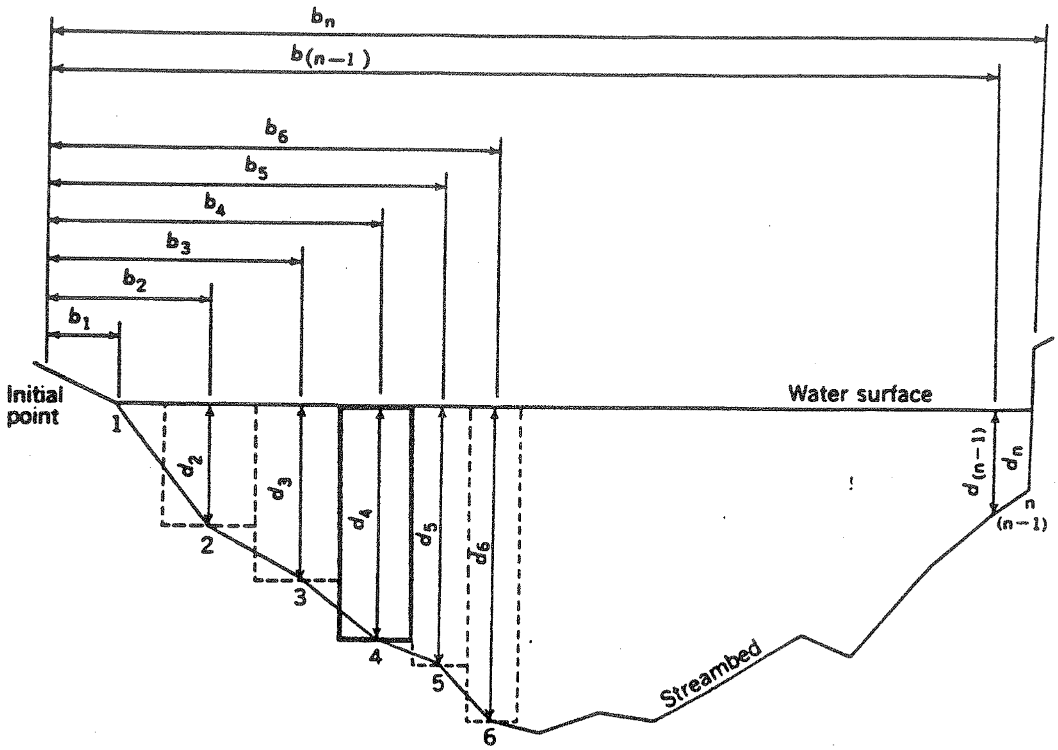
Figure 3

CURRENT METER RATING CHART

3	5	7	10	15	20	25	30	40	Time/Sec.	50	60	80	100	150	200	250	300	350
.183	.292	.401	.565	.837	1.11	1.38	1.65	2.20	40	2.74	3.28	4.37	5.45	8.17	10.88	13.59	16.30	19.02
.180	.286	.392	.552	.818	1.08	1.35	1.62	2.15	41	2.68	3.21	4.26	5.32	7.97	10.62	13.26	15.91	18.55
.176	.280	.383	.539	.799	1.06	1.32	1.58	2.10	42	2.61	3.13	4.16	5.20	7.78	10.36	12.95	15.53	18.11
.172	.273	.375	.527	.780	1.03	1.29	1.54	2.05	43	2.55	3.06	4.07	5.08	7.60	10.12	12.65	15.17	17.69
.169	.268	.367	.515	.763	1.01	1.26	1.51	2.00	44	2.50	2.99	3.98	4.96	7.43	9.89	12.36	14.83	17.2[illegible]
.165	.262	.359	.504	.747	.989	1.23	1.47	1.96	45	2.44	2.92	3.89	4.85	7.26	9.67	12.09	14.50	16.91
.162	.257	.352	.494	.731	.968	1.20	1.44	1.92	46	2.39	2.86	3.80	4.75	7.11	9.46	11.82	14.18	16.5[illegible]
.159	.252	.345	.484	.716	.948	1.18	1.41	1.88	47	2.34	2.80	3.72	4.65	6.96	9.26	11.57	13.88	16.[illegible]9
.156	.247	.338	.474	.701	.928	1.16	1.38	1.84	48	2.29	2.74	3.65	4.55	6.81	9.07	11.33	13.59	15.[illegible]
.153	.242	.331	.465	.687	.910	1.13	1.35	1.80	49	2.24	2.69	3.57	4.46	6.67	8.89	11.10	13.32	15.[illegible]
.151	.238	.325	.456	.674	.892	1.11	1.33	1.76	50	2.20	2.63	3.50	4.37	6.54	8.71	10.99	13.05	15.2[illegible]
.148	.234	.319	.447	.661	.875	1.09	1.30	1.73	51	2.16	2.58	3.43	4.28	6.41	8.54	10.67	12.79	14.9[illegible]
.146	.230	.313	.439	.649	.858	1.07	1.28	1.70	52	2.12	2.53	3.37	4.20	6.29	8.38	10.46	12.55	14.6[illegible]
.143	.226	.308	.431	.637	.843	1.05	1.25	1.67	53	2.08	2.49	3.31	4.12	6.17	8.22	10.27	12.31	14.3[illegible]
.141	.222	.303	.424	.626	.827	1.03	1.23	1.63	54	2.04	2.44	3.24	4.05	6.06	8.07	10.08	12.09	14.[illegible]
.139	.218	.297	.416	.615	.813	1.01	1.21	1.61	55	2.00	2.40	3.19	3.98	5.95	7.92	9.89	11.87	13.[illegible]
.137	.215	.292	.409	.604	.799	.993	1.19	1.58	56	1.97	2.35	3.13	3.90	5.84	7.78	9.72	11.65	13.[illegible]
.135	.211	.288	.402	.594	.785	.976	1.17	1.55	57	1.93	2.31	3.08	3.84	5.74	7.64	9.55	11.45	13.3[illegible]
.133	.208	.283	.396	.584	.772	.960	1.15	1.52	58	1.90	2.27	3.02	3.77	5.64	7.51	9.38	11.25	13.1[illegible]
.131	.205	.279	.389	.574	.759	.944	1.13	1.50	59	1.87	2.24	2.97	3.71	5.55	7.39	9.22	11.06	12.[illegible]
.129	.202	.274	.383	.565	.747	.928	1.11	1.47	60	1.84	2.20	2.92	3.65	5.45	7.26	9.07	10.88	12.6[illegible]
.127	.199	.270	.377	.556	.735	.913	1.09	1.45	61	1.81	2.16	2.88	3.59	5.37	7.14	8.92	10.70	12.[illegible]
.125	.196	.266	.372	.547	.723	.899	1.07	1.43	62	1.78	2.13	2.83	3.53	5.28	7.03	8.78	10.53	12.2[illegible]
.124	.193	.262	.366	.539	.712	.885	1.06	1.40	63	1.75	2.10	2.79	3.47	5.20	6.92	8.64	10.36	12.[illegible]
.122	.190	.258	.361	.531	.701	.872	1.04	1.38	64	1.72	2.06	2.74	3.42	5.12	6.81	8.51	10.20	11.9[illegible]
.121	.188	.255	.355	.523	.691	.858	1.03	1.36	65	1.70	2.03	2.70	3.37	5.04	6.71	8.38	10.05	11.[illegible]
.119	.185	.251	.350	.515	.681	.846	1.01	1.34	66	1.67	2.00	2.66	3.32	4.96	6.61	8.25	9.89	11.5[illegible]
.118	.183	.248	.345	.508	.671	.833	.996	1.32	67	1.65	1.97	2.62	3.27	4.89	6.51	8.13	9.75	11.[illegible]
.116	.180	.244	.341	.501	.661	.821	.982	1.30	68	1.62	1.94	2.58	3.22	4.82	6.41	8.01	9.60	11.[illegible]
.115	.178	.241	.336	.494	.652	.810	.968	1.28	69	1.60	1.92	2.55	3.17	4.75	6.32	7.89	9.46	11.[illegible]
.113	.176	.238	.331	.487	.643	.799	.954	1.27	70	1.58	1.89	2.51	3.13	4.68	6.23	7.78	9.33	10.55

Figure 4

General Cross-Section



EXPLANATION

1, 2, 3, ... n	Observation points
$b_1, b_2, b_3, \ldots\ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots\ldots d_n$	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

—Definition sketch of midsection method of computing cross-section area for discharge measurements.

FIGURE 5

SAMPLE DISCHARGE MEASUREMENT NOTES

Montana Department of Natural Resources and Conservation

Water Resources Division

Bureau of Engineering

DISCHARGE MEASUREMENT NOTES

Date 6-12 19 83

° ____ P.M. X

Time 3:20

G. H. Start ____

G. H. End ____

G. H. Mean ____

Disc. ____

Mean Vel. 2.71 ft/sec.**

Stream Warm Spring Creek

Party Jones Air temp. ____ Water temp. ____ Meter No. Price AA

Station Below B.Doe Diversion at NESE Sec. 14, T12N, R26E

Distant From Initial Point	Width	Depth	Depth of Obser	Rev	Sec	Velocity At Point	Velocity Mean in Vertical	Velocity Mean in Section	Area	Mean Depth	Angle Coef.	Discharge
			L.	E.	W.							
3.4	.30	.00					.00		.00			.00
4.0	.80	.60	.6	20	48		.93		.48			.44
5.0	1.00	1.15	.6	40	51		1.73		1.15			1.99
6.0	1.00	1.70	.6	50	44		2.50	2.42	1.70		.97	4.11
7.0	1.00	2.00	.6	50	42		2.61	2.58	2.00		.99	5.16
8.0	1.00	2.50	.2	50	46	2.39	2.16	2.14	2.50		.99	5.35
			.8	50	57	1.93					.99	
9.0	.75	2.60	.2	60	45	2.92	2.60		1.95			5.07
			.8	50	48	2.29						
9.5	.50	2.80	.2	80	48	3.65	3.43		1.40			4.80
			.8	60	41	3.21						
10.0	.50	2.60	.2	80	46	3.80	3.46		1.30			4.50
			.8	60	42	3.13						
10.5	.50	2.50	.2	80	40	4.37	3.94		1.25			4.92
			.8	80	50	3.50						
11.0	.50	2.00	.6	80	44		3.98		1.00			3.98
11.5	.50	1.80	.6	80	44		3.98		.90			3.58
12.0	.75	1.70	.6	80	51		3.43		1.28			4.39
13.0	1.00	1.65	.6	60	49		2.69		1.65			4.44
14.0	1.20	1.00	.6	30	47		1.41		1.20			1.69
15.4	.70	.60					.70*		.42			.29
	12.00		R.	E.	W.				20.18			54.71
-	3.40											
	15.40											

No. ____ of ____ Sheets Comp by ____ Checked by ____

* Assumed velocity to be 50% of that of the previous partial section.

** 54.71(ft^3/sec.)/20.18(ft^2)

CALCULATING FLOW-RATES USING PUMP AND SYSTEM INFORMATION

On water systems where a pump is used to add energy (head) to the water, the pump may be used as a Pseudo measuring device. Assuming no wear, each model of pump has a unique relationship between the discharge, head, and power input, known as the pump curve. Compared to a flow meter, weir or flume, the use of pump and system information is much more tedious and time consuming. It does, however, offer a fairly accurate (±10% to ±30% error) and inexpensive method of estimating flow rate when no water is flowing and/or when measuring devices are not available.

All of the information shown in "[ ]" refers to information needed in deep well and/or multi-stage pump applications. For our work, column friction will not be significant; however, an approximation may be made by looking at loss in the same size steel pipe.

METHOD #1, PUMP CURVE AND PRESSURE GAGE

Information Needed

1. Pump make, model, impeller diameter [and number of stages].
2. Motor, Hp, RPM, and service factor (S.F. on motor nameplate).
3. Pressure gage reading.
4. Pump suction pipe [or column] length and diameter.
5. Suction lift [or water level in a well].

Calculations

The first two information items are used to locate a pump curve. For a multi-stage pump, a curve will have to be taken from single stage pump information. The single stage curve may be modified by multiplying the head and Hp values by the number of stages. The pressure gage indicates the pressure at its location in the piping system. Any positive inlet pressure, suction pipe friction, or elevation change to the pump must be taken into account. For most centrifugal pumps, only the suction lift needs to be considered. For deep well pumps, both the lift from the well and friction must be considered. The friction and elevation change upstream from the gage plus gage pressure will give the total head on the pump. This pinpoints a location on the pump curve and indicates the pump discharge. When figuring the total head, be sure to convert the gage pressure in psi to feet of head by multiplying by 2.31.

METHOD #2, PUMP CURVE AND SYSTEM INFORMATION

Information Needed

1. Pump make, model, impeller diameter, [and number of stages].

2. Motor Hp, RPM, and service factor.

3. [Water level in a well and column length and diameter] or pump suction lift; suction pipe length, diameter and material (suction information for low head systems only).

4. Mainline size and length and sprinkler spacing.

5. Lateral size and length and sprinkler spacing.

6. Sprinkler nozzle size.

7. For center pivots, determine the pipe size(s) and length(s) and one sprinkler size and space near the outer end. Be sure and note the distance from the pivot point to the sprinkler.

8. The elevation change from the water surface to the highest point in the field.

9. The general system layout.

Calculations

The first two information items are again used to locate a pump curve. The remaining information is used to determine the head on the pump. Center pivot systems will require calculations that have to be done in the office. For all other systems, a system curve will have to be formulated by determining the head necessary to cause a variety of flow rates through the system. Once a number of points for the system head vs. discharge curve are determined, the curve is plotted on the same graph as the pump curve. The flow rate of the system is given by the intersection of the pump and system curves. For our work, we will want to find the system condition (lateral location) that requires the least head. This condition will show the greatest diversion rate. This is somewhat different than the procedure used in pump selection where it is important to select a pump for the highest head conditions.

When determining points on a system curve, a chart such as the one shown in Figure 1 is helpful. It is easiest to select a sprinkler pressure shown on the sprinkler chart and work with that flow rate or combination of flow rates back through the lateral, main, and suction lines [or column]. The friction losses may be determined by using a friction loss slide rule or friction loss chart, although the slide rule is probably the easiest for field work.

When working with wells, it is important to include the depth to water in the well in the "elevation change" column of the worksheet. Sometimes drawdown information is on the well log or a static level might be determined by using a well probe. The static water level will be higher than the dynamic (pumping) condition, but will be some indicator. Using the static water level will tend to overstate the discharge.

METHOD #3, SYSTEM OR PUMP INFORMATION ONLY

Information Needed

1. Pump make, model, impeller diameter and [number of stages].
2. Motor Hp and RPM.

OR

1. Sprinkler nozzle size and number of sprinklers.

OR

1. Mainline size.
2. Lateral size and location on the mainline.

Calculations

The pump information can be used to locate a pump curve. If head information is not available, the flow rate at maximum efficiency could be used as an approximation. The theory is that a pump that is properly selected should operate near maximum efficiency.

If no pump information is available, sprinkler nozzle sizes can be an indicator of system flow rate. If the system is operating, a pitot tube may be used to determine the sprinkler operating pressure.

Knowing the sprinkler operating pressure and the sprinkler nozzle diameter, the sprinkler data in Figures 2 or 3 may be used to determine sprinkler flow rates. The sprinkler flow rate is then multiplied by the number of sprinklers in the system.

If a container of known volume is available, it may be used to determine the flow rate from a single sprinkler. Put a hose over the sprinkler nozzle and time the filling of the container. The volume (gallons) divided by time (minutes) will give the sprinkler discharge.

For an idle system, the sprinkler charts will have to be used and an operating pressure assumed. For most taper bore nozzles on small impact sprinklers, the operating pressure should run from 40-60 psi with the lower pressure more common on smaller nozzles.

If only pipe sizes are available, some flow rate limits may be determined from the five foot per second velocity standard (See Table 1). It should be kept in mind that these figures are guidelines only and only flow rates that are 30% higher than those shown for the pipe size, or lower than the next smaller pipe size should be questioned.

TABLE 1

Flow Rates at Five Feet Per Second

Pipe Size (in.)	1½	2	3	4	5	6	7	8*	10	12	15
Flow Rate (gpm)	30	50	110	200	300	450	600	800	1200	1750	2750

*Use 6" pipe as the next size smaller when checking flow rat

METHOD #4, PUMP HORSEPOWER

Information Needed

1. Pump driver horsepower (electric).

2. As much system information as can be compiled. The most important itmes are:

    1) Change in elevation from the water surface to the high point of the field.
    2) The sprinkler pressure.
    3) The size and length of the mainline.

Calculations

The system head may be determined by adding all of the known components of head. The worksheet in Figure 1 should be of help. Many times only sprinkler pressure and elevation may be known. These are generally the major components of system head so a great deal of error is probably not introduced by ignoring the other items. Knowing the system head, the flow rate may be estimated as follows:

$$Q = 3000 \times P/h$$

WHERE: Q = Flow rate (gpm)
P = Pump power input (Hp)
h = System head (ft)

GENERAL INFORMATION

All motor power values mentioned above refer to electric motors. Electric motors are easy to deal with because they have one rotational speed (RPM) and the power output is clearly evident from the name plate. Information from the engine of an engine driven pump is not totally useless, however. If an engine make and model can be determined, an engine Hp curve (similar in function to a pump curve) might be obtained. If a tachometer is used on the engine, be sure to note the reading. With the engine Hp curve and/or the tachometer reading, some flow rate information may be obtained using the methods mentioned above.

Pump/pressure gage information should yield discharge values that are accurate to within ±10%. If complete data is available for the system, the pump/system information will give results that are ±10% accurate. With poor or missing information, the accuracy of the pump/system method will drop to ±20%.

The methods of sprinkler output at assumed pressure, pipe size, pump at peak efficiency and pump horsepower serve only as guidelines. Only flow rates more than 30% greater or smaller than those predicted should be questioned, except as outlined for pipe sizes. The pump horsepower method may only be accurate to within ±50%.

JB:es

No.	Discharge (gpm)	Sprinkler Pressure (psi)	Sprinkler Pressure (ft)	Lateral Loss (ft)	Main Line Loss (ft)	Column or Suction Loss (ft)	Elev. Change (ft)	Misc. Loss (ft)	Total System Head (ft)

COMMENTS:

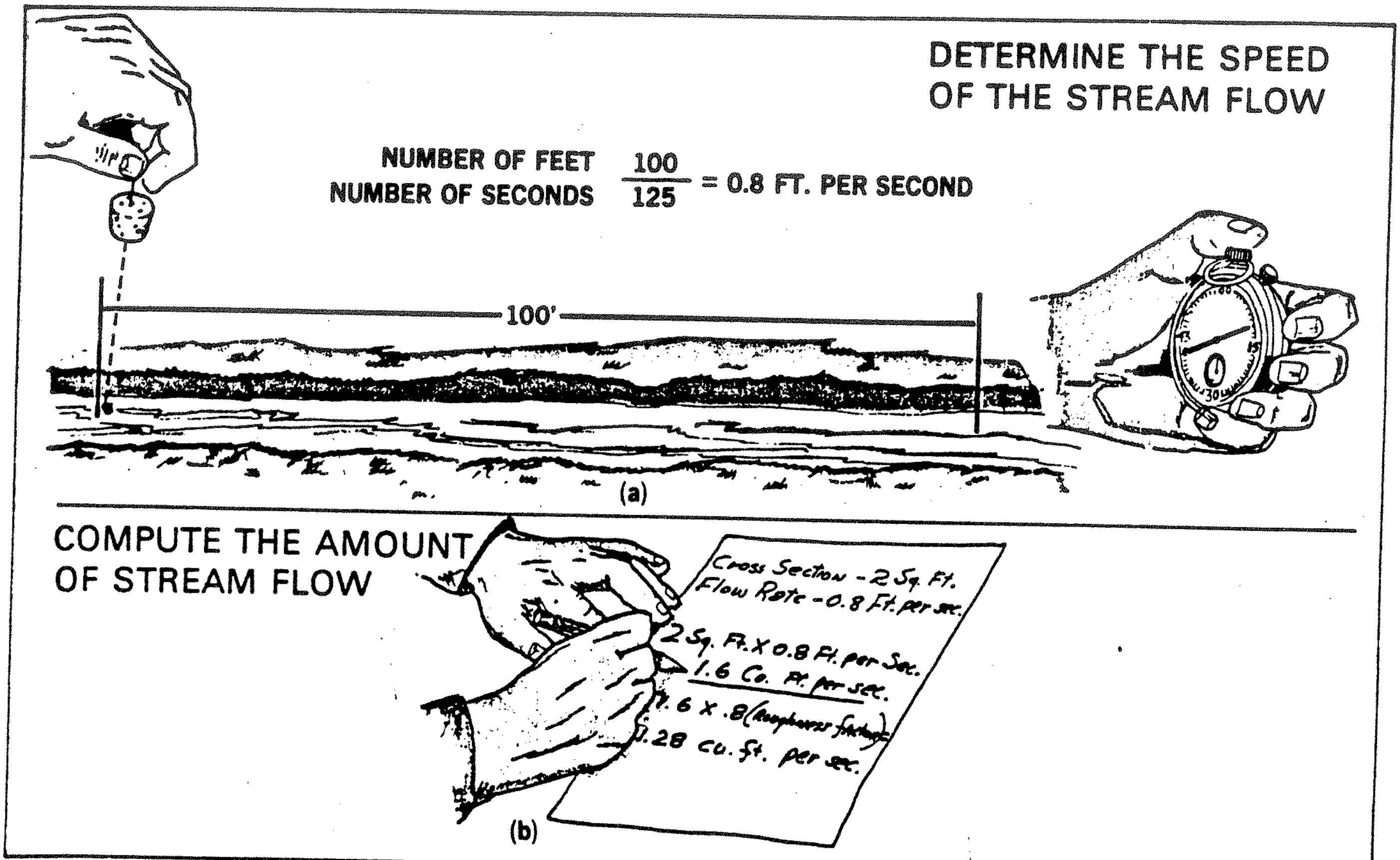


FIGURE 33. Checking and computing the stream flow. (a) Lay out a straight stretch in the stream. Measure the length of the straight stretch in feet. Drop a float in the stream at the up-stream end of the stretch. Check the time required for the float to travel to the other end of the stretch. (b) Then figure the flow.

Water along the banks of a stream flows slower than it does in the center. This is because the banks tend to resist the water flow. This resistance varies with the shape and roughness of the channel.

For most channels, a factor of .8 times the indicated speed of flow is used to get the average velocity.

Example: 1.6 cubic feet per second X .8 = 1.28 cubic feet per second.

FLOW METERS

When flow meters are available, they offer a direct and convenient way to verify flow rate. Most meters allow a direct reading of flow rate from a meter (similar to a speedometer in a car). Some meters measure volume only, and a specified volume must be timed to calculate flow rate.

There are several kinds of flow meters for irrigation and municipal use. Some are electronic while others use a meter to measure a "by pass" or shunt flow. The most common type have a propeller in the pipe which is turned by the flowing water. The comments here apply to the propeller type meter, although installation criteria are given for shunt type meters.

Be sure to consider the following points when making flow meter readings.

1. Know what system conditions are when the flow meter is read.

2. Determine the condition of the meter.

3. Check the installation conditions of the meter.

The flow meter only measures the flow going past it at the time of reading. If part of the system is not being used, the flow will be understated. If a well is turned on to demonstrate the system operation, the flow may be overstated. The high water level in the well will lower the head and increase the discharge. Be sure to find out about any alternative arrangements of system operation from the permittee.

The inline meters are subject to moss buildup on the meter propeller. Actual observation of this problem will be impossible, but keep it in mind. If moss is present in the source and the meter reading is lower than expected, moss buildup may be the reason. It would be advisable to check the discharge by another method under these circumstances.

Meter placement affects both the accuracy and life of the meter. Most manufacturers recommend that the meter be placed at least six pipe diameters downstream and two pipe diameters upstream from any obstructions, valves, elbows, etc. Any reading made from a meter not installed within these standards should be considered suspect.

> EXAMPLE: If a meter is installed in an eight inch diameter pipe, the meter should be at least 48 inches (6x8 inches) downstream from any obstructions. It should also be at least 16 inches (2x8 inches) upstream from any obstructions.

Manufacturers of shunt type meters recommend that the meters be installed at least two pipe diameters downstream from any obstructions. A dealer I contacted recommended installation standards more along the lines of those suggested for propeller type meters.

Fittings such as taps for gages and pressure switches will not cause enough disturbance to affect meter readings. There are some "all in one" meter units which have vanes in the pipe length which is part of the meter. These units do not need the undisturbed pipe lengths discussed above.

Most meters are rated ±2% at full flow. Considering installation problems and the fact that most meters are not operated at full flow, the total error is at least ±5%.

JB:es

NOZZLE DISCHARGE - GALLONS PER MINUTE

p.s.i.	3/21	1/8	9/64	5/32	11/64	3/16	13/64	7/32
	Nozzle Diameter in Inches							
20	1.17	2.09	2.65	3.26	3.92	4.69	5.51	6.37
25	1.31	2.34	2.96	3.64	4.38	5.25	6.16	7.13
30	1.44	2.56	3.26	4.01	4.83	5.75	6.80	7.86
35	1.55	2.77	3.50	4.31	5.18	6.21	7.30	8.43
40	1.66	2.96	3.74	4.61	5.54	6.64	7.80	9.02
45	1.76	3.13	3.99	4.91	5.91	7.03	8.30	9.60
50	1.85	3.30	4.18	5.15	6.19	7.41	8.71	10.10
55	1.94	3.46	4.37	5.39	6.48	7.77	9.12	10.50
60	2.03	3.62	4.50	5.65	6.80	8.12	9.56	11.05
65	2.11	3.77	4.76	5.87	7.06	8.45	9.92	11.45
70	2.19	3.91	4.96	6.10	7.34	8.78	10.32	11.95
75	2.27	4.05	5.12	6.30	7.58	9.08	10.66	12.32
80	2.35	4.18	5.29	6.52	7.84	9.39	11.02	12.74
85	2.42	4.31	5.45	6.71	8.07	9.67	11.35	13.11
90	2.49	4.43	5.61	6.91	8.31	9.95	11.69	13.51
95	2.56	4.56	5.76	7.09	8.53	10.2	11.99	13.86
100	2.63	4.67	5.91	7.29	8.76	10.5	12.32	14.23

AVERAGE APPLICATION RATE - INCHES PER HOUR

Spacing Feet	Gallons Per Minute From Each Sprinkler 2	3	4	5	6	7	8	9	10	12
20X20	.48	.72	.96	1.20	1.44	1.70	1.93	2.16	2.40	
20X30	.32	.48	.64	.80	.96	1.12	1.28	1.43	1.60	1.93
20X40	.24	.36	.48	.60	.72	.84	.96	1.08	1.20	1.45
30X30	.21	.32	.43	.54	.64	.75	.88	.96	1.07	1.28
30X40	.16	.24	.32	.40	.48	.56	.64	.72	.80	.95
30X50	.13	.19	.25	.32	.38	.45	.51	.58	.64	.76
40X40	.12	.18	.24	.30	.36	.42	.48	.54	.60	.72
40X50	.10	.14	.19	.24	.29	.34	.38	.43	.48	.58
40X60		.12	.16	.20	.24	.28	.32	.36	.40	.48

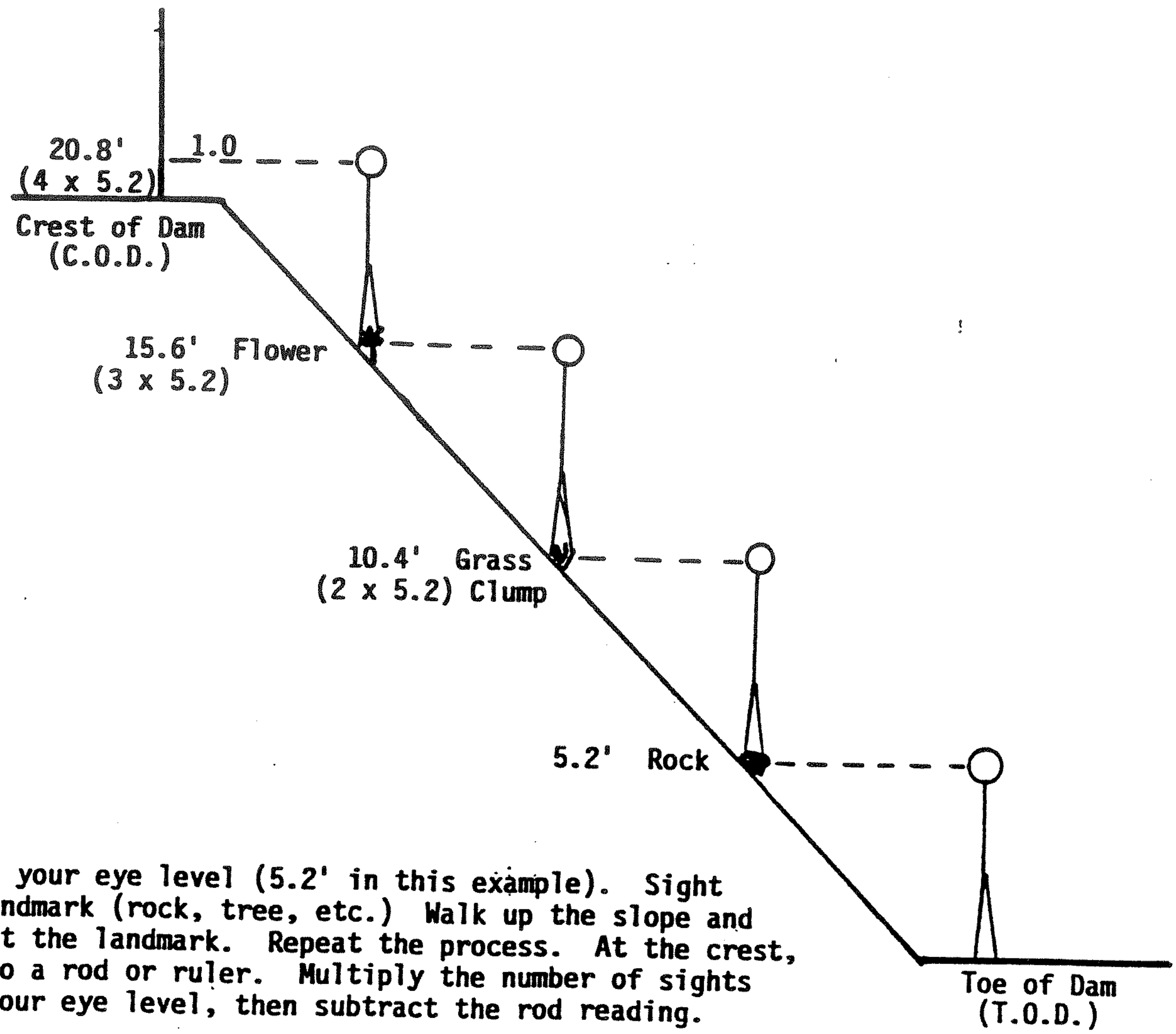
WATER APPLIED PER SET - ACRE INCHES AT 70% EFFICIENCY

Application Rate of System - Inches Per Hour

Hours Per. Set	.12	.14	.16	.18	.20	.22	.24	.26	.30	.35	.45	.55
1	.08	.10	.11	.13	.14	.15	.17	.18	.21	.25	.32	.39
2	.17	.20	.22	.25	.28	.31	.34	.36	.42	.49	.63	.77
3	.25	.29	.34	.38	.42	.46	.50	.55	.63	.74	.95	1.16
4	.34	.39	.45	.50	.56	.62	.67	.73	.84	.98	1.26	1.54
5	.42	.49	.56	.63	.70	.77	.84	.91	1.05	1.23	1.58	1.93
6	.50	.59	.67	.76	.84	.92	1.01	1.09	1.26	1.47	1.89	2.31
7	.59	.69	.78	.88	.98	1.08	1.18	1.27	1.47	1.72	2.21	2.70
8	.67	.79	.90	1.01	1.12	1.23	1.34	1.46	1.68	1.96	2.52	3.08
9	.76	.88	1.01	1.13	1.26	1.39	1.51	1.64	1.89	2.21	2.84	3.47
10	.84	.98	1.12	1.26	1.40	1.54	1.68	1.82	2.10	2.45	3.15	3.84
11	.92	1.08	1.23	1.39	1.54	1.69	1.85	2.00	2.31	2.70	3.47	4.24
12	1.01	1.18	1.34	1.51	1.68	1.85	2.02	2.18	2.52	2.94	3.78	4.62
15	1.26	1.47	1.68	1.89	2.10	2.31	2.52	2.73	3.15	3.68	4.73	5.78
18	1.51		2.02	2.27	2.52	2.77	3.02	3.28	3.78	4.41	5.67	6.93
[illegible]	1.76	2.06	2.35	2.65	2.94	3.23	3.53	3.82	4.41	5.15	6.62	8.09
24	2.02	2.35	2.69	3.02	3.36	3.70	4.03	4.37	5.04	5.88	7.56	9.24
30	2.52	2.94	3.36	3.78	4.20	4.62	5.04	5.46	6.30	7.35	9.45	11.55

DAM HEIGHT MEASUREMENT

USING A HAND LEVEL

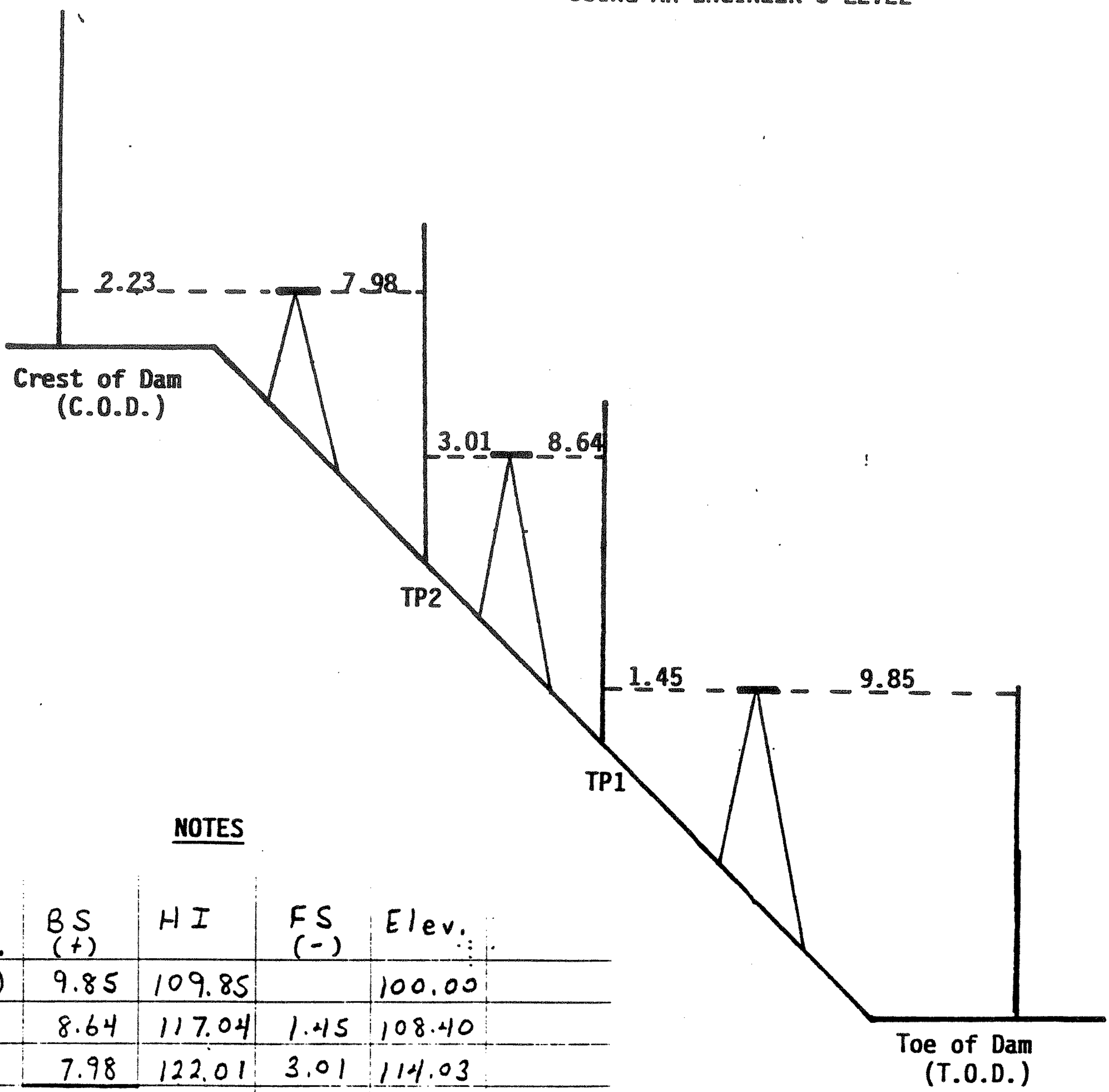


Measure your eye level (5.2' in this example). Sight to a landmark (rock, tree, etc.) Walk up the slope and stand at the landmark. Repeat the process. At the crest, sight to a rod or ruler. Multiply the number of sights times your eye level, then subtract the rod reading.

Example: 4 x 5.2' = 20.8' less rod reading of 1.0' = 19.8'

DAM HEIGHT MEASUREMENT

USING AN ENGINEER'S LEVEL



Elevation 100.00 ft.*

NOTES

Sta.	BS (+)	HI	FS (-)	Elev.
T.O.D	9.85	109.85		100.00
TP 1	8.64	117.04	1.45	108.40
TP 2	7.98	122.01	3.01	114.03
C.O.D	+26.47		2.23	119.78
	-6.69		-6.69	
	+19.78			

Check

T.O.D	100.00
	+ 19.78
C.O.D.	119.78

*Arbitrary elevation, used for elevation difference only.